NSRP 0469

SHORT COURSE ON

DESIGN FOR PRODUCTION INTEGRATION

COURSE NOTES

[VERSION 11/95]

A TRAINING INITIATIVE
OF
THE UNIVERSITY OF MICHIGAN
FOR
THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

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FIRST DAY AGENDA

8 - 8.30 AM	INTRODUCTIONS
8.30 - 8.45 AM	WORKSHOP OBJECTIVES
8.45 - 9.30 AM	PARADIGM SHIFT
9.30 - 10.00 AM	**BREAK**
10.00 - 11.00 AM	WORLD SHIPBUILDING MARKETS
11.00 - 11.30 PM	EXERCISE 1 - Selection of Ship Type
11.30 AM - 12.30 PM	**LUNCH**
12.30 - 1.15 PM	PRODUCTIVITY
1.15 - 2.00 PM	COMPETITIVENESS
2.00 - 2.15 PM	**BREAK**
2.15 - 3.15PM	EXERCISE 2 - CGT/Manhours OR Cost Breakdown
3.15 - 4.00PM	NEED FOR CHANGE

SECOND DAY AGENDA

8 - 8.30 AM	FIRST DAY REVIEW
8.30 - 9.15 AM	PRODUCTION ENGINEERING
9.15 - 9.45 AM	GROUP TECHNOLOGY
9.45 - 10.00 AM	**BREAK**
10.00 - 10.30 AM	SHIPBUILDING POLICY AND BUILD STRATEGY
10.30 - 11.00 AM	PRODUCT WORK BREAKDOWN STRUCTURE
11.00 - 11.30 AM	EXERCISE 3 - Coding
11.30 AM - 12.30 PM	**LUNCH**
12.30 - 1.30 PM	DESIGN FOR PRODUCTION IN BASIC DESIGN
1.30 - 2.15 PM	DESIGN FOR PRODUCTION IN DETAILED DESIGN
2.15 - 2.30 PM	**BREAK**
2.30 - 3.00 PM	DESIGN FOR PRODUCTION IN DETAILED DESIGN
3.00 - 3.45 PM	EXERCISE 4 - Team Debate on DFP
3.45 - 4.00pm	WRAP-UP

WORKSHOP OBJECTIVES AND DESIRED OUTCOMES

UMTRI'S GOALS FOR COURSE

- SATISFY YOUR EXPECTATIONS
- TRANSFER OUR KNOWLEDGE ABOUT DESIGN FOR PRODUCTION
- GIVE YOU AS MUCH HANDS ON LEARNING AS POSSIBLE
- HAVE YOU LEAVE FEELING IT WAS ALL WORTHWHILE AND READY TO BE A DFP CHAMPION IN YOUR ORGANIZATION

DESIRED OUTCOME

IF WE SUCCEED, AT END OF COURSE YOU WILL CLEARLY KNOW

- WHAT HAPPENED IN THE COURSE
- WHAT IS THE SIGNIFICANCE OF WHAT HAPPENED
- WHAT YOU WILL DO AS A RESULT OF THE COURSE

NATIONAL SHIPBUIDLING RESEARCH PROGRAM

WORLD SHIPBUILDING MARKETS, DEMAND AND SUPPLY

DESIGN FOR PRODUCTION INTEGRATION

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
601 PAVONIA AVENUE, JERSEY CITY, NJ 07306
Paper presented at the 1995 Ship Production Symposium
Westin Hotel, Seattle, Washington, January 25-27, 1995

Marketing Strategy for Merchant Shipbuilders

Paul W. Stott (V), A&P Appledore International, U.K.

ABSTRACT

Much has been published over the years about technology and productivity in shipbuilding, and much also about the shipbuilding market and its potential. Little has been published to-date however, about the all important techno-economic interface between the two.

This paper sets out to explore this interface, and to identify how a shipyard can be matched to its external environment through the adoption of a coherent strategy. The elements of external forces are considered (in particular prices and market volume), and the internal factors within the control of a shipyard are examined to review how they can be utilized in a strategic sense to match a shipyard to a targeted market sector.

The elements reviewed include

- Prices,
- Exchange rates,
- Physical constraints,
- Capacity,
- Market volume,
- Production characteristic-s and
- Shipyard organization.

INTRODUCTION

"Consumption is the sole end and purpose of all production and the interests of the product ought to be attended to, only so far as it may be necessary for promoting that of the consumer."

(Adam Smith "The Wealth of Nations" - 1776).

Over the past decades, much effort and expenditure has been directed at performance improvement in shipyards, with the aim of reducing costs. This has particularly been the case in higher cost countries with shipyards seeking to offset wage costs against productivity.

Performance is about much more than just productivity, however. Whilst the number of manhours used per ton produced is of course vitally important there are other factors that have a considerable bearing on a shipyard's bottom line, some of which are outside the shipyard's control.

These factors are put into context by examining the relationship between a shipyard and its marketing environment Whilst numerous papers have been written about performance within a shipyard and about the market outside, few have addressed the all important techno+economic interface between the two.

The marketing environment within which a shipyard operates includes internal factors, generally within the control of the shipyard, and external factors outside the control of the shipyard. The internal factors that can be manipulated to cope with changes in the external environment are normally termed the 'Marketing Mix' (Lancaster and Massingham, 1988). Generally grouped under the four 'Ps', these factors are

the design and attributes of the Product to match customer requirements;

the design and attributes of the Place in which production takes place, encompassing not only production attributes

but also organization and in particular overheads.

the Promotion of the product being offered, i.e., advertising or other channels to draw the product to the attention of potential customers; and

the Price at which the product is offered, although as will be demonstrated later, this aspect is largely outside the control of merchant shipbuilders.

The external factors affecting the shipyard, over which it has little or no control, are numerous and wide ranging, including politics and macro-economics. The more tangible factors in the immediate environment of the shipyard (termed the "proximate macro-environment" in marketing jargon), on which most marketing strategies will comcemtrate, include the following:

- Market Price,
- Competition,
- Wage Rates and Costs,
- Exchange Rates, and
- Demand.

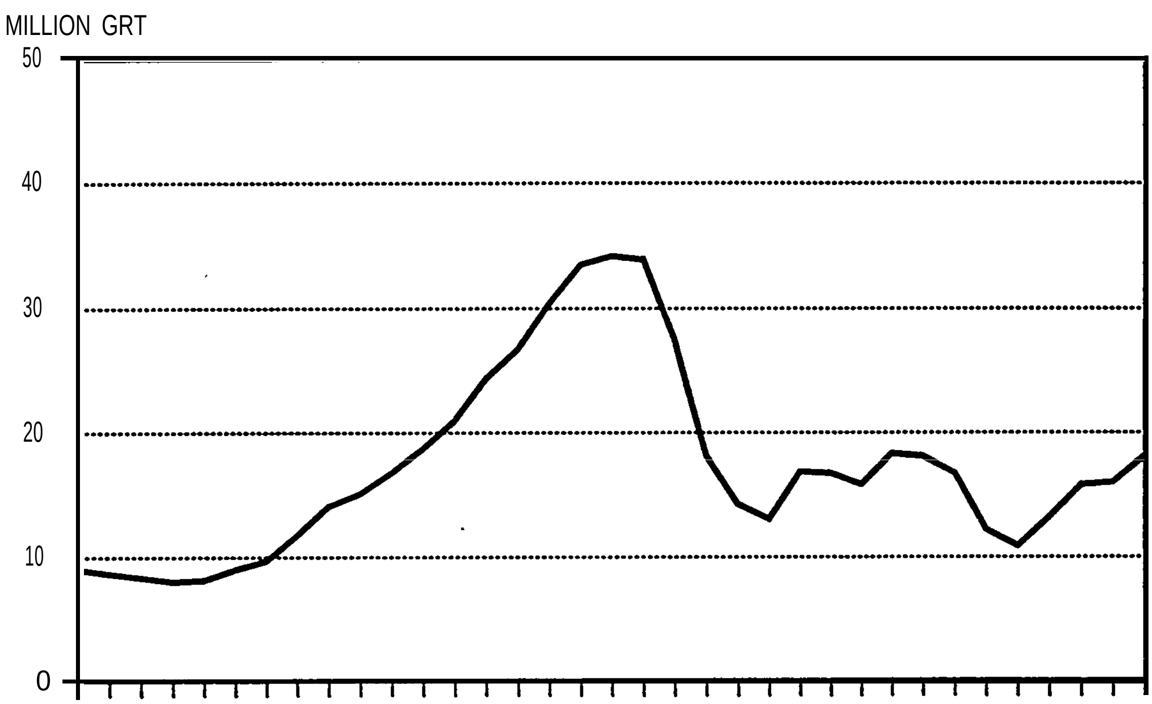
When considering these factors it should be kept in mind that the external environment presents not only the threats against which a company has to react but also the opportunities of which it can take advantage.

It is important to understand the way in which a shipyard interacts with its environment, as well as the elements of strategy available to a shipyard in seeking to match the attributes of the market. Decisions relating to production must take into account a global strategy, including reference to the external environment, and not simply be based on a continuous drive to minimize manhours.

HISTORICAL BACKGROUND

For much of the past 10 to 15 years, commercial shipbuilding has not presented an economic opportunity for most of the world's shipbuilders, however productive they might be. The market collapsed following a peak of newbuilding in the mid 1970s, and has remained at a low level for more than a decade, as shown in Figure 1.

The depressed level of capacity utilization



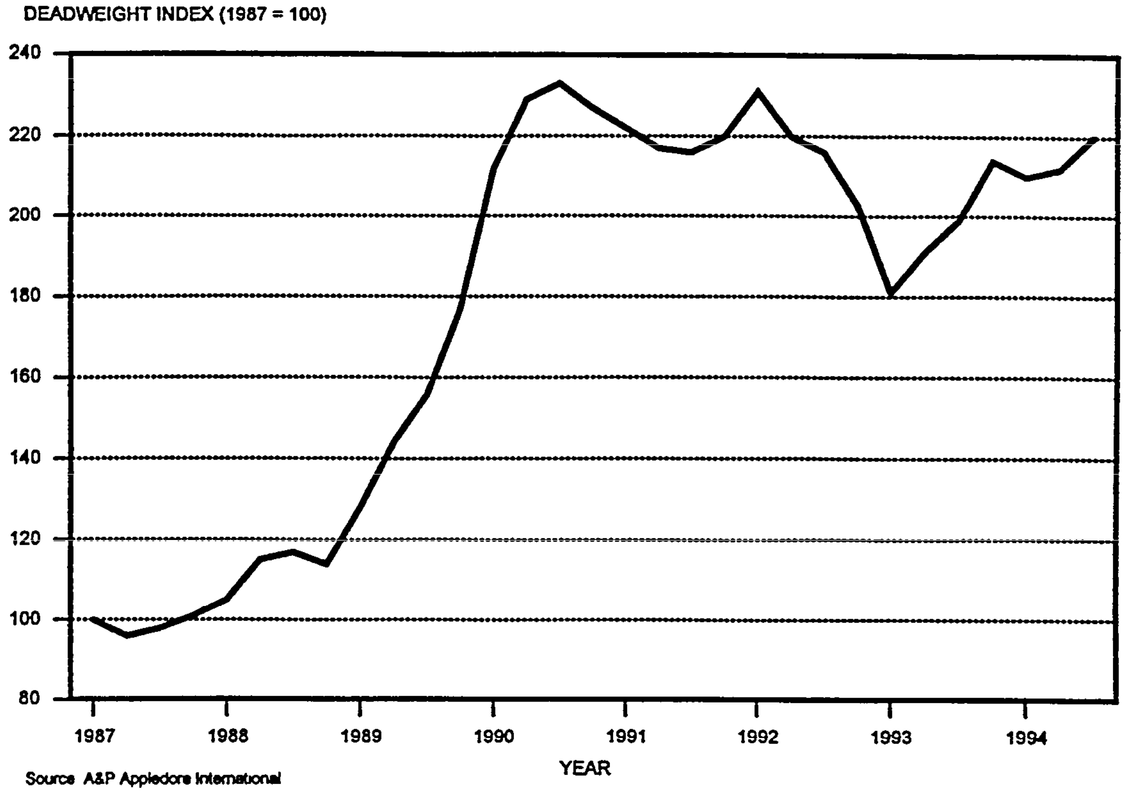


Figure 2 : Orderbook Deadweight Index

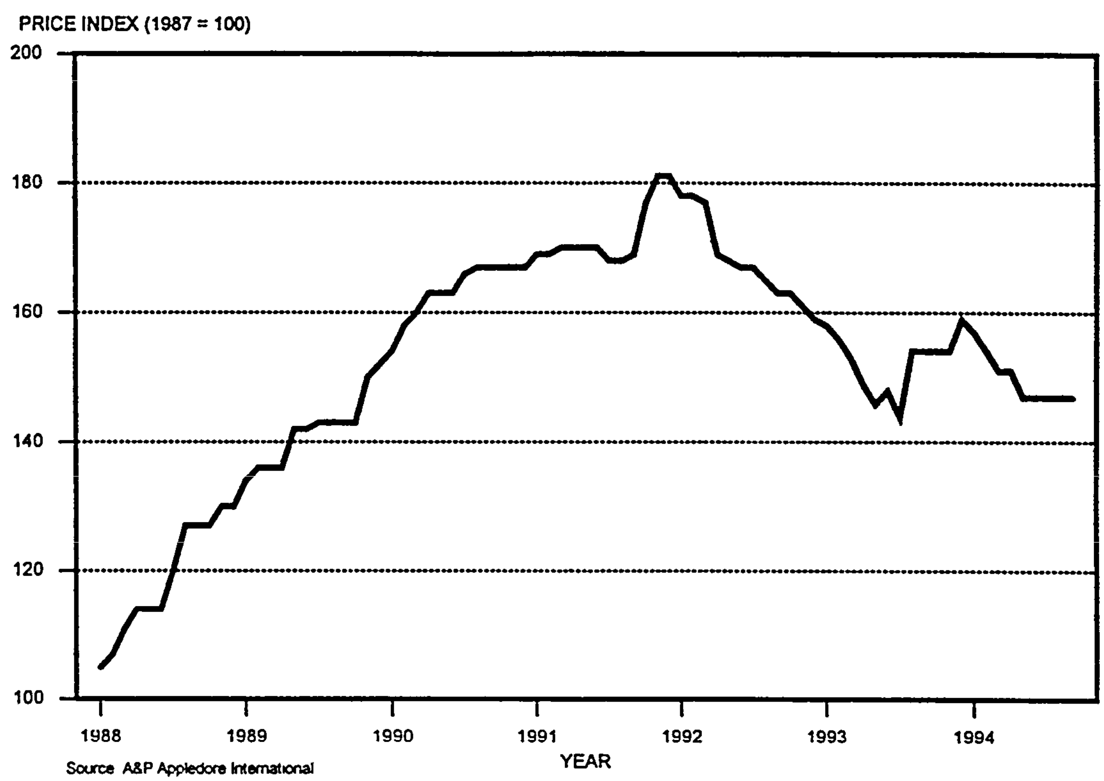


Figure 3 : Newbuilding Price Index

during this period, with correspondingly low prices, led to the closure of numerous shipyards (or in some cases entire national industries), with those shipyards remaining requiring government support and intervention to survive.

Since around 1987, however, the level of international ordering has picked up, with corresponding improvements in capacity utilization and prices. (Figure 2 presents the growth in orders since 1987 and Figure 3 the development of prices over the same period). Following the period of extended restructuring and rationalization, the industry is well placed to absorb this increase in demand without the massive degree of over-capacity seen at the start of the last decade. Having said this, prices have yet to rise to a point such that much of the world's shipbuilding industry can reliably generate a profit and subsidies are still common practice in many countries.

Demand for new vessels is generated primarily by the need to replace obsolete, aged tonnage, which has reached the end of its economic life, and by the need for the fleet to expand to accommodate growth in trade. In addition to these two primary determinants, demand for new vessels is also generated by technical developments, such as the development of containerization, or by legislative pressure, such as the implementation of 0PA90 in the USA which discriminates against aging, single skin tankers.

These factors are illustrated in Figure 4, which presents a simplified diagram of the shipbuilding market and the shipping market. (Note: The second hand sector of the shipping market has deliberately been left out of this diagram for the sake of clarity. For a full description of the economics of the shipping trades, the reader is referred to Stopford, 1988).

As a consequence of the lack of newbuilding between the mid 1970's and the late 1980's, the average age of the fleet is high, at around 17 years. In the face of an economic life expectancy of between 20 and 25 years, the prospects for fleet replacement in the coming decade are good, particularly when coupled to escalating concerns amongst governments, charterers, insurers and classification societies about the large volume of aging and sub-standard tonnage currently trading. A second consequence of the historic lack of newbuilding has been that much scrapped tonnage has not been replaced and the level of surplus tonnage within the fleet, and thereby its ability to absorb fluctuations in demand, has been reduced and growth in trade therefore leads more directly to demand for new tonnage.

Against this background, most forecasts of newbuilding for the coming decade are optimistic and shipbuilders are gearing up for improved demand, although it has to be said that there are structural problems in all sectors of the market that could cast a shadow over the awaited recovery. These factors are discussed in full in Peters, 1993. This potential opportunity has arisen at a time when many shipyards are looking for opportunities to replace declining workloads for warships, following the so-called "peace dividend".

This is the situation to a large extent in the United States. Most US shipyards have not been active in the international commercial sector for

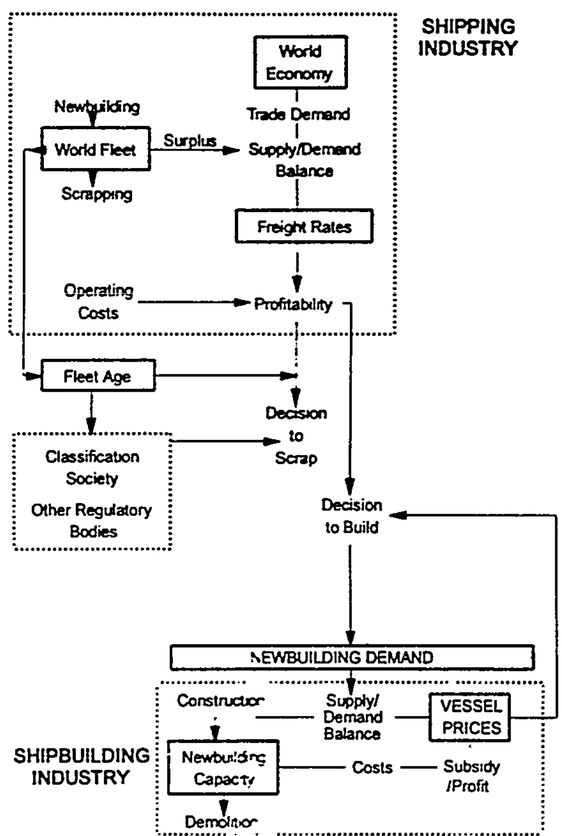


Figure 4 Market Drivers and Key Determinants

some years, and are currently seeking ways to capitalize on the potential for commercial newbuilding.

In reality, a shipyard does not operate in isolation and does not have a free hand to construct whatever it chooses. The environment (in the broad sense of the word) imposes constraints within which a shipyard must operate and which will dictate at least partially the range of ships that may be included in its product mix.

THE CORRECT STRATEGY?

When faced with a blank order book a shipyard must make a decision as to the market sector to be targeted. This decision has often in the past been made intuitively, due to lack of defined methods or constraints against which to analyze the product mix.

Successful entry by into the merchant shipbuilding sector will be a matter of strategy. The era when shipyards could aim to construct all types of vessels according to market demand has finished, and most shipbuilders now specialize. This enables organizations and facilities to be correctly matched to the target market sector. The strategy requires very careful consideration, especially because it is easy to get it wrong.

A good example of a common intuitive strategy is one that would aim to build sophisticated ships, to capitalize on high levels of technology in the high wage cost countries. This seems to be a perfectly rational approach and is one that has been adopted in the past, in particular in some European shipyards; but some of the underlying assumptions require careful consideration.

Firstly, this strategy wrongly assumes that the price of a ship is related to its work content. In other words, that a more sophisticated ship will attract a higher price. This is unfortunately not true, as can be seen from Table 1, comparing a sophisticated container ship with a more simple panamax tanker.

The income per unit of work as measured by compensated gross tons (Kattan and Clark, 1993), is higher for the less sophisticated, larger ship than for the container ship, despite the seemingly attractive higher price of the former smaller vessel. To be rigorous the added value rather than price should be compared to work content. After subtracting material costs, the relative number become $750 added value per unit of work for the tanker, and $665 for the container ship.

Ship prices move on a commodity basis, rising and falling with supply and demand, as can be seen by studying Figure 3, the price index. The price is, in general, not within the control of the shipyard.

Secondly, the strategy outlined above confuses the sophistication of the product with the sophistication of the process. A passenger ship is a good example of a sophisticated ship type that uses a high level of traditional and labor intensive shipbuilding skills. Series building of simple bulk carriers, on the other hand, permits the maximum utilization of sophisticated automated processes and robotics, making best use of advanced production technologies available in developed countries. It also minimizes labor content where labor cost is a disadvantage.

	2,500 TEU Container Ship	80,000 DUW Tanker
Price (February 1994)	$45 million	$44 million
Gross Tonnage	37,000	46,000
Compensated Gross Tonnage	27,750	25,300
Income per CGT	$1,621	$1,739

Table 1

The most appropriate strategy may, in fact, be counter-intuitive and its derivation requires very careful thought with respect to a number of factors.

ECONOMIC INFLUENCES

The implications of price not being within the control of the shipyard requires further study. A survey of potential shipowners was undertaken recently by the author to investigate the attributes that make up a marketable design, and buyer values. The following attributes were reviewed:

- Price,
- Delivery,
- Financing,
- Minimum Crew,
- Ease of Operation,
- Ease of Maintenance,
- Speed,
- Fuel Consumption/Economy,
- Capacity,
- Efficient Cargo Handling,
- Safety,
- Design/Operational Considerations, and
- Other Factors.

Whilst many of the design attributes were seen as having a positive benefit on the marketability of a design, owners (within reason) were not willing to pay a premium above the market price to reflect performance attributes. In other words, the quality of the design of a ship may be reflected in the probability of attracting a sale, but not in the price.

The effect of fluctuating prices is compounded by another factor outside the control of the shipyard: exchange rate fluctuations. These fluctuations can have a very significant effect on the economic performance of a shipyard that is almost totally outside management control. These effects are demonstrated by the following financial calculations, considering the all important but simple gross margin calculations. (Warnes, 1984).

Table II presents an example of a simple gross margin calculation, taken from an actual case.

Price	$19.4 million
Labor Costs I .	$6.1 million
Material Costs :	$10.5 million
Overheads :	$ 1.0 million
Profit	$1.8 million

I Including associated overhead costs

Table II

A 5% fall in price (around $1 million) leads to a fall in profits of over 50%, and a fall of 10% leads the shipyard into a marginal position. Conversely, a rise of 5% leads to an increase in profit of over 50% and a rise of 10% leads to more than double the profit. A quick glance at Figure 3 shows that price fluctuations of this magnitude are not uncommon.

To put this into perspective, compare it to an increase of 10% in productivity on the same calculation (represented by a 10% reduction in labor costs). This leads to a reduction in total cost of 3% and an increase in profits of around 34%. It should be kept in mind that an improvement of 10% in productivity is not a trivial target and is likely to require considerable expenditure of effort and possibly capital as well.

The second factor that is outside the control of a shipyard is exchange rate fluctuations.

Table III presents two examples, firstly, in yen with the price fixed in dollars, with the movement in exchange rate between January and December 1993, secondly, with the calculation undertaken in sterling with the price fixed in dollars, and the movement in exchange rates over the second half of 1992.

These calculations use selected exchange rates to illustrate a point. However, the effect is clear. In the case of the Japanese shipyard profit would have fallen from 9% of turnover at the start of the year to a loss of almost 3% at the year's end. Conversely, the profit at a UK yard would have risen from 9% to over 27% over the six month period shown, without any internal change in the shipyard.

The aim of presenting these simple and fairly obvious calculations is to demonstrate that external economics have a significant

Calculation 1: Price Fixed in US Dollars, costs in Yen

Price (Millions)	**19.4**
Exchange Rate 1	125 Jan 1993
Exchange Rate 2	110 Dec **1993**
Labor Cost	763 million Yen
Material Costs	1,313 million Yen
Overhead Costs	125 million Yen
Total Costs :	2,201 million Yen

Profit Calculations in Mllion Yen

	Jan 1993	Dec 1993
Income	2,426	2,141
costs	2,201	2,201
Profit	225	(60)
Profit: Income	9.28%	-2.80%

Calculation 2: Price Fixed in US Dollars, coats in Sterling

Price (Million $)	19.4
Exchange Rate 1	0.52 **Jully** 1992
Exchange Rate 2	0.65 Dec 1992
Labor Cost	£3.17 million
Material Cost	£5.46 million
Overhead Cost	£O.52 million
Total Costs:	£9.15 million

Profit Calculations in Million Pounds Sterling

	July 1992	Dec 1992
Income	10.09	12.61
costs	9.15	9.15
Profit	-0.94	3.46
Profit: Income	9.30%	27.44%

Table Ill Effects of Exchange Rate Fluctuations

influence in shipbuilding, and can be of overriding importance.

STRATEGY, TARGET MARKETING AND PRODUCT MIX SELECTION

The dangers of coming to strategic conclusions on an intuitive basis were outlined above. To arrive at a considered and objective strategy, a number of factors have to be taken into consideration. When faced with a blank sheet of paper, and the need to define a successful product mix, constraints are required against which to set targets.

The remainder of this paper discusses a number of considerations and constraints that have to be taken into account when deriving a strategy for a target product mix, under the headings listed below

- Physical Constraints,
- Market Volume, Market Share and other Market Factors,
- Production Characteristics and Organization, and
- Other Strategic Options.

PHYSICAL CONSTRAINTS

The simplest set of constraints to consider are the physical constraints of the shipyard : length, beam, depth of water and capacity. Shipyards can be classed according to the generic ship type corresponding to the maximum size of ship that could be constructed. This is difficult to classify exactly, due to the imprecise nature of terms but corresponds very roughly to:

- Small Ships (below 5,000 dwt),
- Sub-handysize (5,000 to around 20,000 dwt),
- Handysize/Handymax (20,000 up to around 45,000 dwt),
- Panamax (60,000 to 90,000 dwt),
- Cape Size (100,000 to 170,000 dwt),
- VLCC (over 200,000 dwt).

In general these size bands are very loose: only panamax and suezmax have an actual physical constraint and the generic terms are open to wide interpretation. The small ship sector is particularly dificult to classify. Below around 5,000 dwt the characteristics of the market change significantly and this sector forms a complex sub-market in its own right. (This paper concentrates predominantly on the market for larger tonnage).

All shipyards are constrained by size, although this constraint can of course be relaxed through investment, if a positive cost benefit situation is Identified. In general term, larger shipyards have an advantage. This is not

	Handymax Tanker	Panamax Tanker
Estimated Current Price*	$33 million	$42 million
Estimated CGT	15,120 tonne	22,160 tonne
Income per CGT	$2,182	$1,895

* July 1994

Table IV

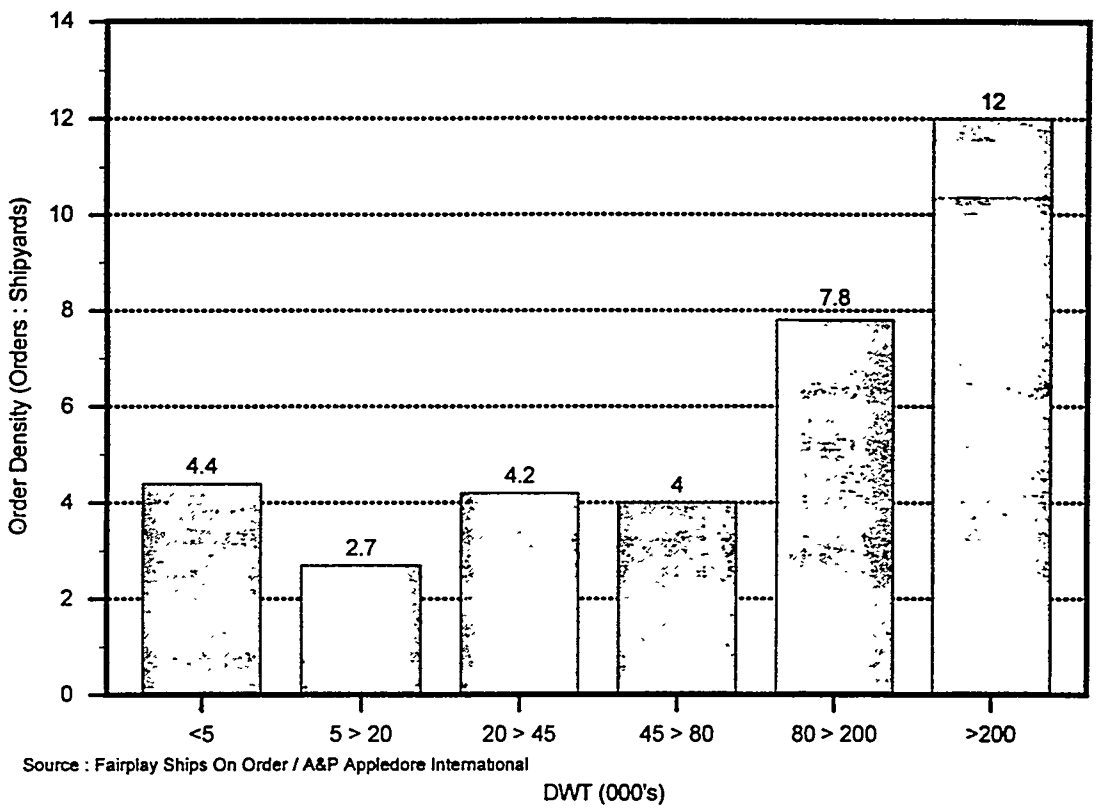


Figure 5 : Order Density in the Tanker Market

because larger ships necessarily attract higher value as demonstrated by the calculation presented in Table IV comparing the income per unit of work (represented by the Compensated Gross Ton) for a handysize and a panamax tanker.

Market conditions for the handymax ship at the time of writing this paper are significantly better than in the panamax sector, so handymax ships attract a correspondingly better price.

The advantage for the larger shipyard lies in the fact that it can "trade down" to build smaller vessels, if that is what the market demands, giving an added flexibility. The smaller shipyard cannot trade up. This is illustrated in Figure 5 which considers order density in the tanker market, that is the ratio of the number of ships on order in a sector of the market to the number of shipyards participating in that sector. (These graphs are based on a sample of 1,407 tankers ordered or on order since 1989). Competition

reduces as the size of the ship increases. At the far end of the scale, i.e., VLCCs, the level of competition is much reduced, and a number of shipyards are currently anticipating the replacement of the VLCC fleet when prices could be good, due to the balance between supply and demand in this sector. Price per unit of work for a VLCC is currently around the same level as the handymax sector, but this may be adversely affected by new capacity due to come on stream in Germany, South Korea and China. This could upset the fine balance in this sector.

Thus, it can be seen from Figure 5 that, whilst market volumes are greatest in the smaller sizes, competitive conditions improve as size increases.

Initially the decision as to whether to relax an existing constraint in a shipyard is a fairly simple matter of economics, considering the cost and the perceived benefit. However, the cost is likely to be high, and ultimately the decision must be made on the perception of the risk associated with the expenditure, in addition to simple economic calculations.

Finally, there is a need to match the physical capacity of a shipyard with the level of workforce.

Capacity is very difficult to Specify in exact terms. It is a function of many parameters including surface area, cranage, equipment, launching arrangements and above all people. The most useful measure of capacity is output (measured by compensated gross tons) per manyear worked. For example, a shipyard of 1,000 persons, operating at a reasonably productive level of output of 50 CGT produced per manyear worked, would have a capacity of 50,000 CGT per year or around 3.5 handymax bulk carriers. If the shipyard has restricted berth space (particularly if it is unable to build in tandem or semi-tandem), or perhaps even more critically if it has restricted berth cranage, then launching this many ships could be a problem. Conversely, 50,000 CGT equates to roughly one 125,000m^3 LNG carrier per year, the production of which may not be constrained by the launcning bottleneck.

MARKET VOLUME, MARKET SHARE AND OTHER MARKET FACTORS

It is not the intention to present here a specific market forecast. However, it is important to gauge the relative sizes of market sectors, to judge the size of the target that is being aimed at. This is illustrated in a nondimensional format in Table V.

TARGET MARKET VOLUMES

Ship Type	Relative Market Volume
Bulk Carrier	**62.3**
General cargo	**53.5**
Tanker	**31.5**
container	**21.6**
Passenger (including Ferries)	**17.4**
Chemical Tanker	**17.1**
RoRo	**13.9**
Reefer	**12.8**
OBO	**1.3**
LPG	**5.0**
LNG	**1.0**

Table V

The statistics in this Table are based on a recent market forecast undertaken by the author for ships between 5,000 and and 100,000 dwt. The smallest market sector, LNG carriers has been assigned a factor of 1. The other sectors have been assigned a factor based on the relative size of the market. For example, for every 1 LNG ship constructed, 21.6 container ships will be constructed

In terms of volume, the market can be divided into three sectors as shown in Table VI.

Volume Markets :	Bulk Carrier General Cargo Tanker
Intermediate	Container Passenger Chemical Tanker RoRo Reefer
Niche	OBO LPG LNG

Table VI

The implications of these classifications in terms of market share are important." For the shipyard outlined above as capable of producing 50,000 CGT per annum, equating to 3.5 bulk carriers or one 125,000 m^3 LNG carrier, the implied levels of market share would be around 6'% of the bulk carrier market but well over 80% of the LNG market. It follows from this that a shipyard with 2,000 workers aiming to specialize in the LNG sector would be short of work.

A strategy aiming at niche sectors has to be very carefully considered. The intermediate sector is also not without its problems. For example, 99 container ships were delivered in 1993, representing a peak of deliveries in this sector. The container ship market is forecast to improve, but not to a level significantly greater than the deliveries seen in 1993, although demand is likely to be steadier than seen in the 1980's and early 1990's. The caveat to this is that a new market entrant aiming a strategy in this sector is likely to have to gain market share at the expense of established specialist builders and competition will be intense. Market entry will be difficult. Conversely, in the volume sectors of the market market share can be gained through the significant market growth that is forecast, giving a greater likelihood of successful market penetration.

Finally under this heading, the characteristics of likely orders should be considered.

In the volume sector, series orders or standard ships can be expected, with low cycle times leading to high throughput. This leads potentially to high economic efficiency in high cost countries, with overhead or establishment costs being recovered over high throughput, minimizing unit costs.

At the other end of the spectrum, in the niche sectors, orders are more likely to be for one-offs, with long cycle times and low throughput. In some cases, an entire company overhead may have to be recovered against a single vessel, or even less than one vessel if the cycle time is greater than one year. This is considered further in the following section.

PRODUCTION CHARACTERISTICS AND ORGANIZATION

Production characteristics vary significantly depending on the target market sector. This is best illustrated by considering two ships at the opposite ends of the spectrum a bulk carrier and a cruise ship. Various aspects of the production system are contrasted below for these two ship types.

Automation/Skill.

High volumes and the high level of repetitive steelwork permits maximum use of automation in the construction of bulk carriers, requiring minimum craft skill levels. Conversely, passenger ship construction is difficult to automate and relies more heavily on craft skills.

Skill Balance.

For the bulk carrier the emphasis is largely on steelwork with the reverse being the case for the passenger ship where outfit content predominates.

Throughput Characteristics.

High volume flow throughput for bulk carriers permits the use of process orientated workflow. In the case of passenger ships, the long cycle time leads to a much more product orientated flow, with the ship being the primary workstation for much of the time.

Organization.

Workstations remain largely fixed for much of the work involved in bulk carrier production with fixed operatives. Passenger vessel are better suited to multi-discipline teams working in ad hoc workstations and zones.

Overheads.

The repetitive nature of series ship production enables overhead staff to be minimized in the case of bulk carrier production. This permits maximum economic efficiency, with low overheads recovered against high throughput. Conversely, higher numbers of planners, technical staff, QA and inspection staff, estimators, purchasers, supervisors and most

Attribute	Tanker		Cruise Vessel
Market Volume	High	← Increasing Volume	Low
Target Market Share	Low	Increasing Market Share →	High
Order Characteristics	Series	← Increasing Order Length	Unique
Cycle Time	Short	Increasing Cycle Time →	Long
Automation Potential	Maximum	Increasing Skill Level →	Minimum
Skill Balance	Steel Trades	Increasing Outfit Content →	Outfit Trades
Throughput	High Volume	← Increasing Throughput Volume	Low Volume
Overheads	Low	Increasing Overhead Costs →	Higher
Potential For High Economic Efficiency	High	Increasing Unit Cost →	Low
Production Organization	Defined Flow Lanes	← Increasing Fixed Workstations	Ship Orientated

Figure 6 : Comparison of the Attributes of Volume and Niche Market Building

other overhead categories are required for passenger ship production.

The above factors are summarized, along with the market elements, in Figure 6. This figure demonstrates that production facilities must be matched to the target product mix. It would clearly not be efficient to construct a bulk carrier in a passenger ship facility, or vice versa, although technically it could be done. This is the reason why shipyards can no longer be all things to all shipowners, as they were 30 years ago, and that most successful shipyards today specialize in selected target areas. The target that most closely matches warship construction for those shipyards attempting to convert, is cruise ship construction. It should be clear from the above that attempting to build volume ship types efficiently in a former warship shipyard is likely to be difficult without investment and possibly downsizing, in particular of overhead staff.

Mixing non-compatible ship types, such as bulk carriers and passenger ships, in the same facility should be technically and economically feasible, but would require very careful thought and planning. In particular, the allocation of overheads would have to be carefully considered so as not jeopardize the economic viability of the more simple ship types.

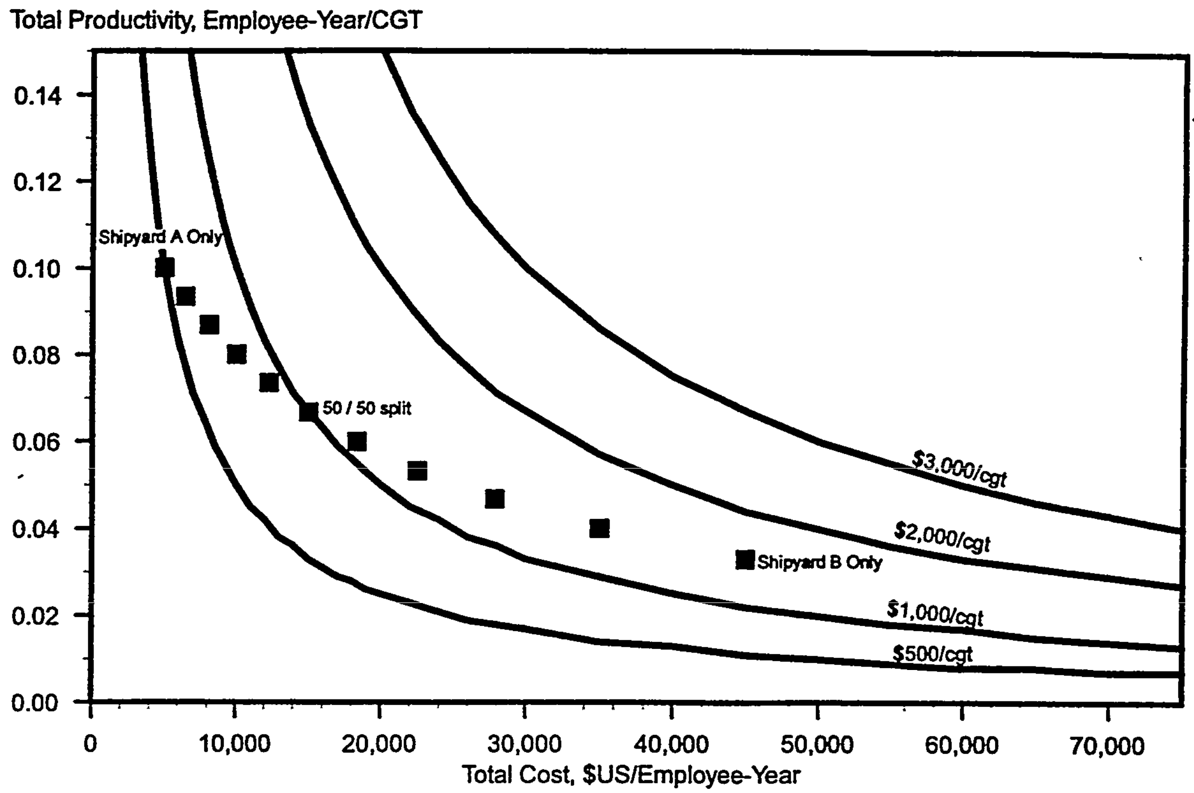


Figure 7 : Combined Series Order Effect On Competitiveness

OTHER STRATEGIES : ORDER SHARING

In addition to target marketing and the matching of facilities and organization to the chosen product mix, there are other options that could be utilized as part of an overall strategy.

As an example, the following calculations concern a strategy of combining a series order in two shipyards at different levels of competitiveness. The measure of competitiveness utilized is cost per unit of output, the unit of output used being the Compensated Gross Ton.

Consider the case of a reasonably competitive shipyard in a high cost country, that proposes to form an association with a less efficient shipyard in a low cost country, with the aim of reducing unit costs of a series order built jointly in the two shipyards. This is illustrated in Figure 7.

Figure 7 is based on curves of constant cost per unit of output (Kattan and Clark, 1993), taking into account total cost per employee (horizontal axis) and productivity (vertical axis) measured by employee years used per Compensated Gross Ton produced. Total cost includes labor costs and overhead costs, but excludes material costs and other contract costs such as builder's risk insurance or financing charges. The product of the two parameters gives a measure of competitiveness; cost per CGT produced.

Shipyard A is typical of a developing country, with low productivity, but a very low operating cost, giving a level of competitiveness of $500 per CGT.

Shipyard B is typical of an average level in Europe with a reasonable level of productivity but a fairly high cost, giving a level of competitiveness of $1,500 per CGT.

The components of these costs are presented in Table VII.

Shipyard A:	Productivity	:	0.1* manyears per CGT
	Cost per manyear		$5,000
	Performance	:	$500 per CGT
Shipyard B:	Productivity	:	0.033** manyears per CGT
	Cost per manyear		$45,000
	Performance	:	$1,500 per CGT

* an output of 10 CGT per manyear worked
** an output of 30 CGT per manyear worked

Table VII

Share of Order (Shipyard A : B) A	B	Combined Cost per CGT	% Improvement Unit Costs
0	100	1,500	0
10	90	1,400	6.67
20	80	1,300	13.33
30	70	1,200	20
40	60	1,100	26.67
50	50	1,000	33.33
60	40	900	40
70	30	800	46.67
80	20	700	53.33
90	10	600	60
100	0	500	66.67

Table VIII: Combined Series Order Effect on Competitiveness

Table VIII presents the combined level of competitiveness depending on the proportion of the order placed in either shipyard and the percentage reduction in cost per unit output from the situation in Shipyard B alone.

The validity of this strategy is clear from this Table. Significant reductions in cost per unit output are possible via this course of action, without any improvement in productivity in the higher cost shipyard. A 50:50 split of the order would lead to a reduction in unit costs of one-third.

The aim of presenting these calculations is to show, again, that strategy is not simply a matter of looking inwards to improve those factors under the control of the shipyard. As indcated in the introduction to this paper, external factors outside the control of the shipyard produce both opportunities and threats, and creative ways must be sought to maximize the advantage from the former, and minimize the problems from the latter. Order sharing is one example of a possible strategy to do this.

CONCLUSIONS

Shipyards do not operate in isolation. They are subject to forces imposed by the external environment to which they must react. The external environment provides both opportunities and threats, and the nature of the external environment must be understood to enable these to be identified and addressed.

In general, external forces are outside the control of a shipyard. In particular this comment is directed at price, which fluctuates on a commodity basis. It is one of the characteristics of the shipbuilding industry, that very large fluctuations in price have been experienced in the past and it is largely due to this variation that shipbuilding is seen as a dificult and high risk industry.

In order to survive in this difficult environment, a shipyard must adopt a coherent strategy to match the facilities and organization to a targeted market sector. This strategy must be considered very carefully, with decisions made on a rational and scientific basis, and not on intuition.

When deriving a strategy, the following factors must be considered:

- Physical constraints : There will be a maximum size of vessel that can be constructed and a limit to capacity, although both these constraints can normally be relaxed if this is justified;
- Market factors : the capacity of a shipyard can be related to market volume for specific target sectors, and the market share required to achieve reasonable throughput can be identified. These must be reviewed along with the competitive situation to identify the potential for market sector penetration; and
- Production characteristics and organization: The characteristics of a shipyard must be matched to the chosen target market sectors. At different ends of a spectrum the

characteristics are highly automated, high throughput and low overhead to higher craft skill level, low throughput and high overhead.

Finally, an example is presented of a potential strategy based on sharing orders between shipyards at different productivity levels. The aim to this strategy is to reduce unit costs without changing the internal characteristics of either shipyard.

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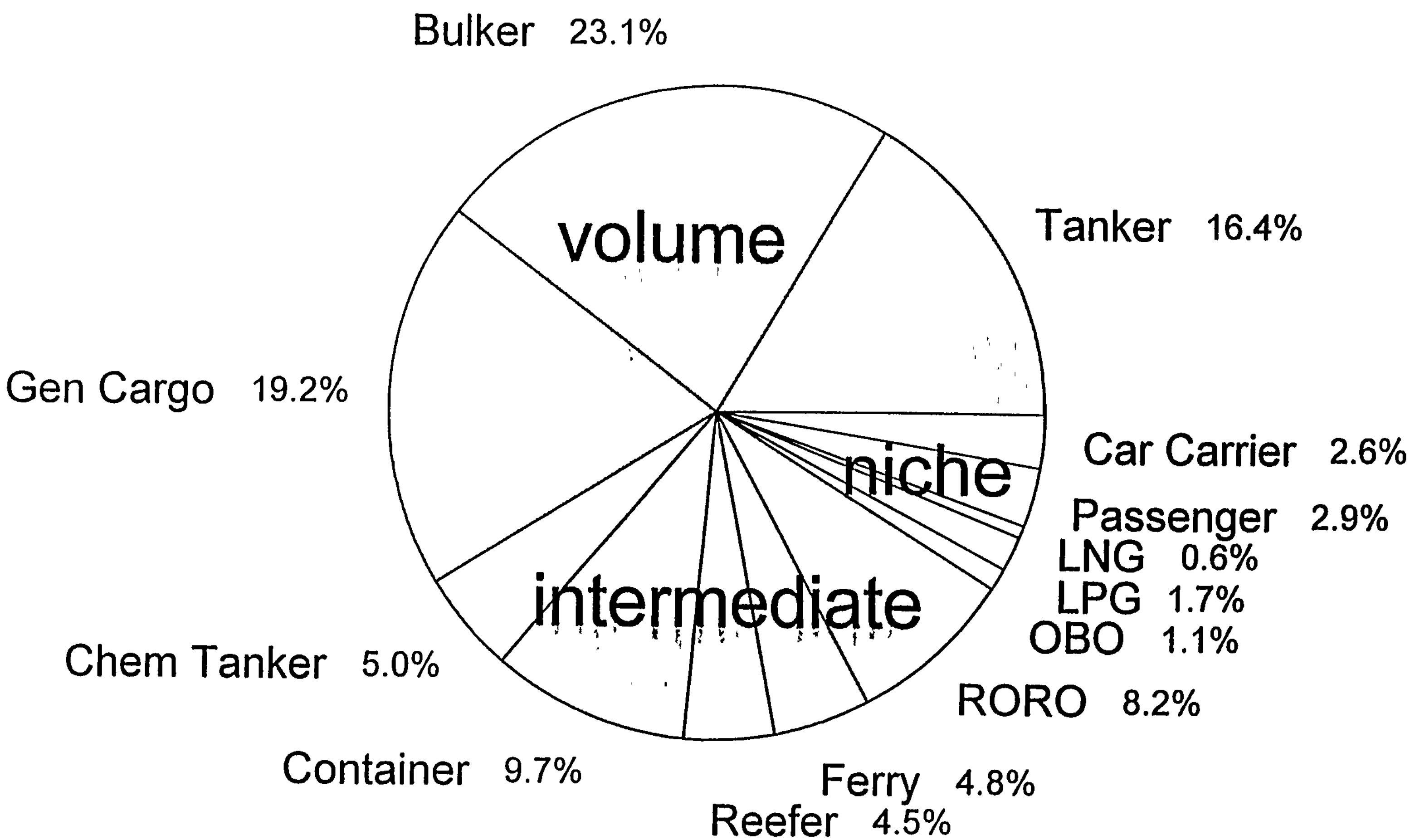
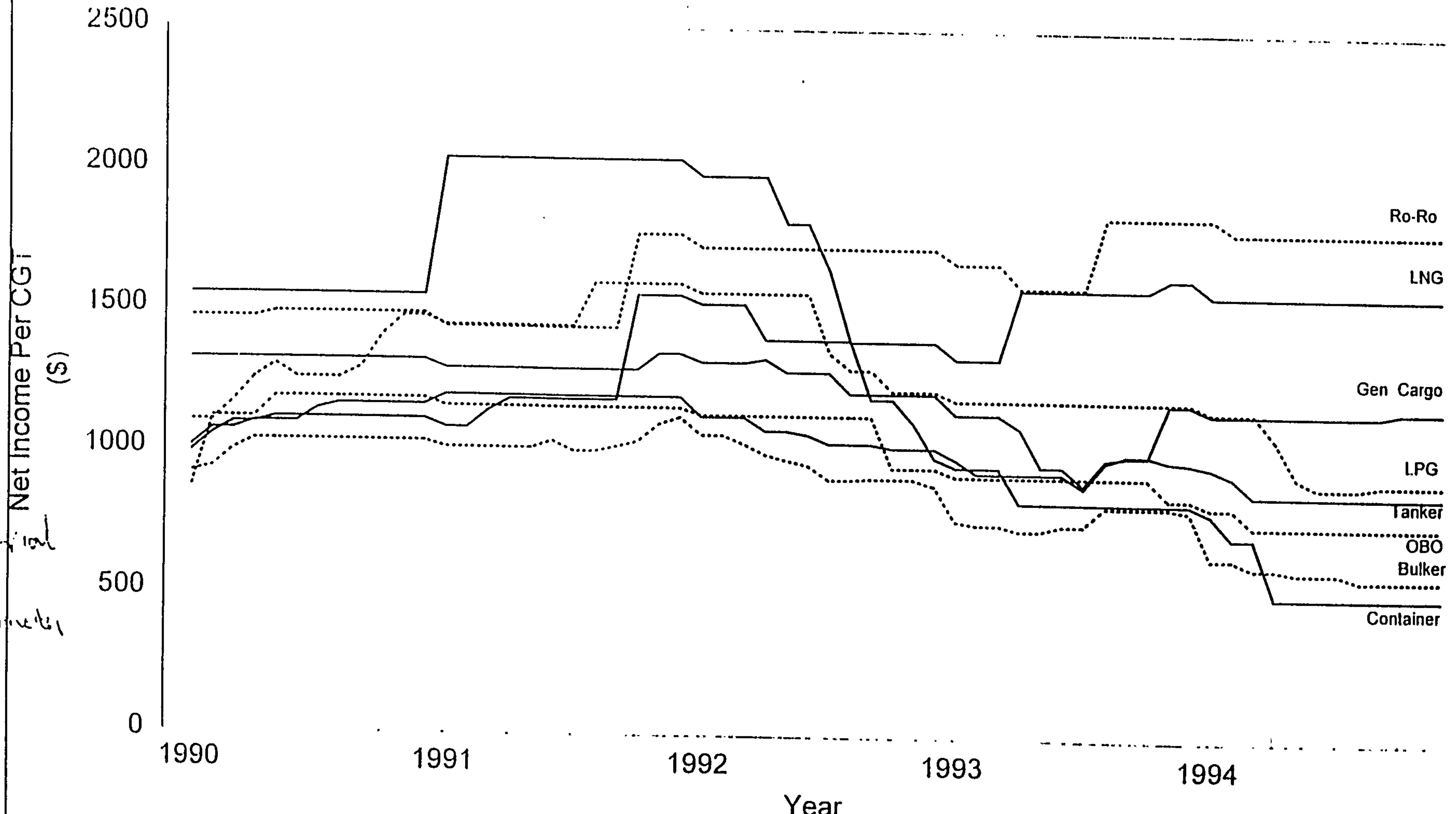
Demand Characteristics (No. Contracts)



PRICE PER UNIT OUTPUT

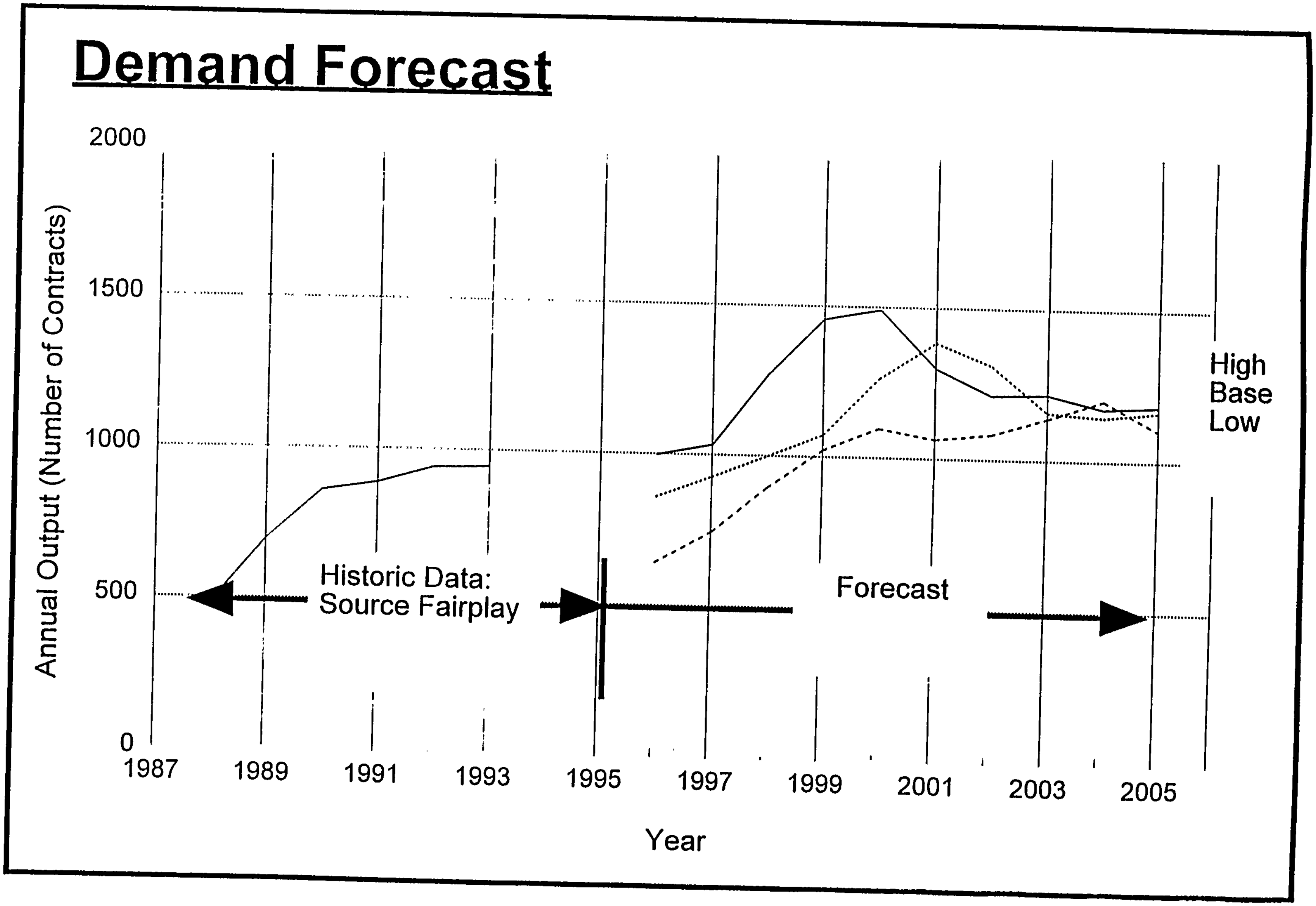
(1990 - 1994)

Material cost subtracted



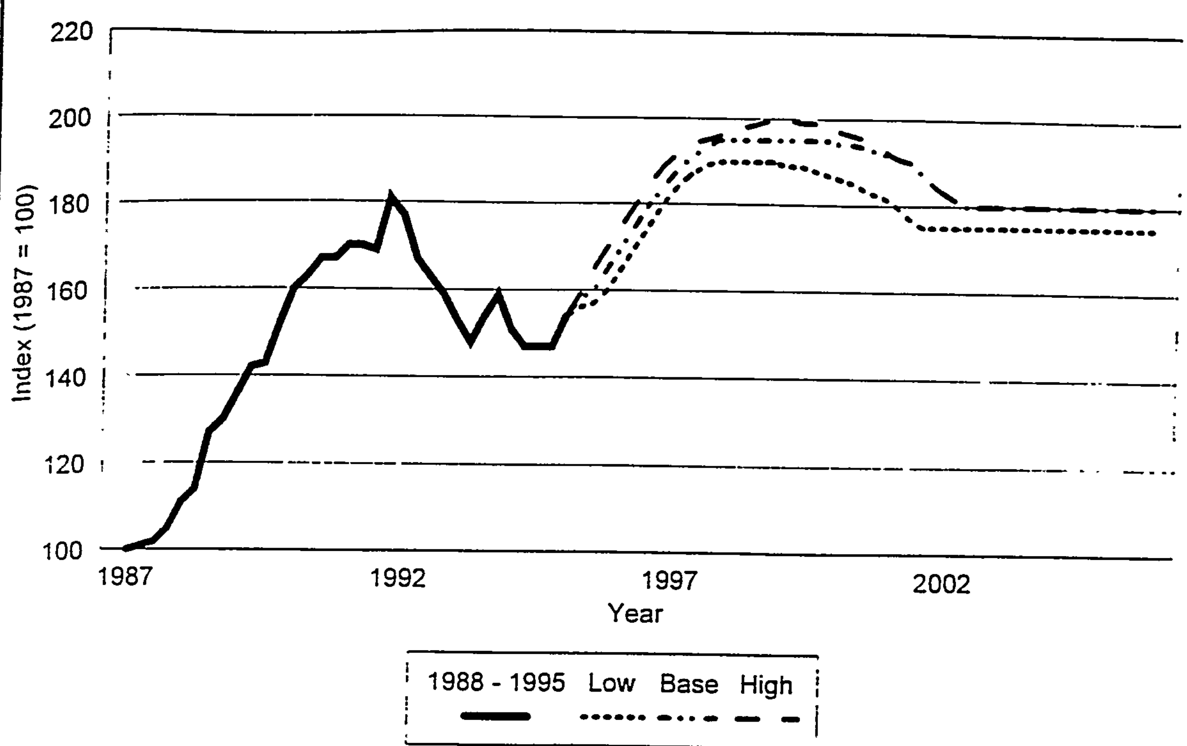
[Source: L.S.E / APAI]

Used to discuss correct selection of sector



Demand Forecast
2000
1500
1000
500
0
Annual Output (Number of Contracts)
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
Historic Data:
Source Fairplay
Forecast
High
Base
Low

FORECAST PRICE INDEX



Source: APAI

EXERCISE 1

SELECTION OF SHIP TYPE

NSRP SP-9 (EDUCATION AND TRAINING) PANEL
SHORT COURSE

DESIGN FOR PRODUCTION INTEGRATION

EXERCISE 1

YOU ARE THE MANAGEMENT TEAM OF A SHIPYARD CURRENTLY BUILDING COMBATANTS AND YOU HAVE DECIDED TO ENTER THE INTERNATIONAL COMMERCIAL SHIPBUILDING MARKET.

WHAT SHIP TYPES WOULD YOU SELECT FOR YOUR PRODUCT RANGE AND WHY?

NATIONAL SHIPBUILDING RESEARCH PROGRAM

PRODUCTIVITY

DESIGN FOR PRODUCTION INTEGRATION

- HOW TO MEASURE PRODUCTIVITY

  SALES $ PER EMPLOYEE (DIRECT/TOTAL)

  PROFIT $ PER EMPLOYEE (DIRECT/TOTAL)

  PROFIT PERCENTAGE PER EMPLOYEE (DIRECT/TOTAL)

- IF PRODUCTIVITY IS DEFINED AS OUTPUT/INPUT

  - OUTPUT CAN BE MEASURED AS:

    -NET TONS STEEL BURNED/FABRICATED/ERECTED/WELDED/ETC.

    -NUMBER OR WEIGHTS OF PIPE ASSEMBLIES

    -AREA OF BULKHEADS ERECTED

    -NUMBER OF "STANDARD" HOURS PRODUCED

    -VALUE ADDED <— SALES

  - INPUT CAN BE MEASURED AS:

    -DIRECT WORKERS MAN-HOURS

    -DIRECT AND INDIRECT MAN-HOURS

    -LABOR + CAPITAL + MATERIALS + ENERGY

- OBVIOUSLY, IMPROVEMENTS IN PRODUCTIVITY CAN BE ACHIEVED BY INCREASING OUTPUT WITH SAME INPUT OR MAINTAINING OUTPUT WITH A REDUCED INPUT OR A COMBINATION OF BOTH.

- A&P APPLEDORE WAS HIRED BY BRITISH SHIPBUILDERS TO STUDY PRODUCTIVITY IMPROVEMENT IN THE SHIPYARDS.

- THE STUDY IDENTIFIED "PRODUCTIVITY GAP" BETWEEN WORLD'S BEST AND U.S.A. AND U.K. SHIPYARDS.

o PRODUCTIVITY MEASUREMENT IN SHIPYARDS

- MH/TON
- TON/MH X AREA
- MH/JWL
- COST/DWT TON
- COST/LIGHTSHIP TON
- STEEL COST/TON -> NOT GOOD AS WE KNOW LIGHTEST SHIP IS NOT LEAST COST, SO COST/TON EXAGGERATES PARAMETER; I.E.,

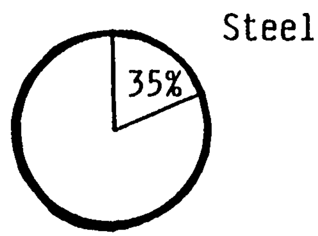
$$\frac{\text{LOW COST}}{\text{HIGH WEIGHT}} = \text{LOW PARAMETER}$$

- OUTFIT COST/TON
- MACHINERY COST/TON
- LABOR COST/RUN

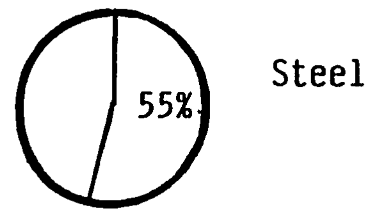
o STANDARD PRODUCTIVITY IS BUDGET.

o PRODUCTIVITY FACTOR $\frac{\text{BUDGET}}{\text{ACTUAL}}$

° KNOW WHERE WORK CONTENT IS:



FRIGATE



14,000 CARGO SHIP

	FRIGATE	14,000 CARGO SHIP
STEEL	600,000 MH	210,000 MH
OUTFIT	2,000,000 MH	190,000 MH

BERTH STEEL WORK MANHOURS ARE 55% OF TOTAL STEELWORK.

FOR EXAMPLE:	IN SHOP/ON PLATENS	1 MH FOR 1.3 FT JWL
	ON BERTH	1 MH FOR 0.2 FT JWL

- STEEL LABOR RATE DEPENDS ON THREE MAIN FACTORS:

  (1) SHIP TYPE

  (2) SHIP SIZE

  (3) NUMBER OF IDENTICAL SHIPS TO BE BUILT

- OTHER FACTORS ARE: - PRODUCTION METHODS
  - CRANE LIFTS
  - ADVANCE OUTFITTING

- FOR EXAMPLE, LSD-41 HAS 6500 L, TONS OF STEEL AND BASED ON DRY CARGO VESSELS DESIGNED TO ABS OF SIMILAR WEIGHT, THE LABOR RATE FOR ONE VESSEL CONTRACT WOULD BE 54 MH/TON.

- HOW DOES LSD-41 WARRANT A MUCH HIGHRR RATE?

- THIS DIFFERENCE CAN BE JUSTIFIE BY:

  CALCULATING AVERAGE PLATE THICKNESS/TON OF STEEL WEIGHT

  DETERMINE JOINT WELD LENGTH/TON OF STEEL 'WEIGHT

  FOR THE LSD-41, THE FIRST PARAMETER WOULD BE TWICE THE CARGO SHIP VALUE, AND THE SECOND WOULD BE 5 TO 8 TIMES.

- THEREFORE, RATIO FOR LSD-41 COMPARED TO TYPICAL CARGO VESSEL WOULD BE

$$(2 \times .4) + (\overset{\boxed{8}}{5} \times .35) = \overset{\boxed{3.60}}{2.55}$$

Proportion affected
by thickness

Proportion affected
by weld length

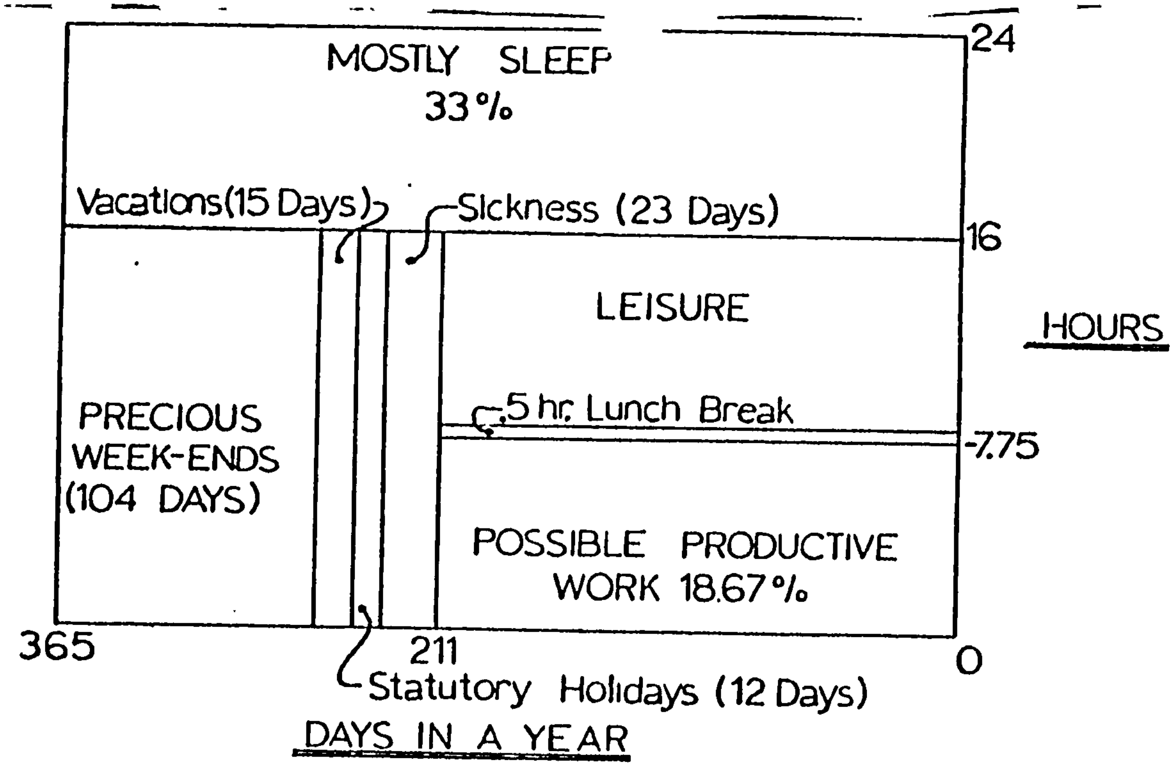
- DEMING LAMENTS "NOBODY SEEMS TO UNDERSTAND (EXCEPT THE JAPANESE) THAT AS YOU IMPROVE QUALITY YOU IMPROVE PRODUCTIVITY".

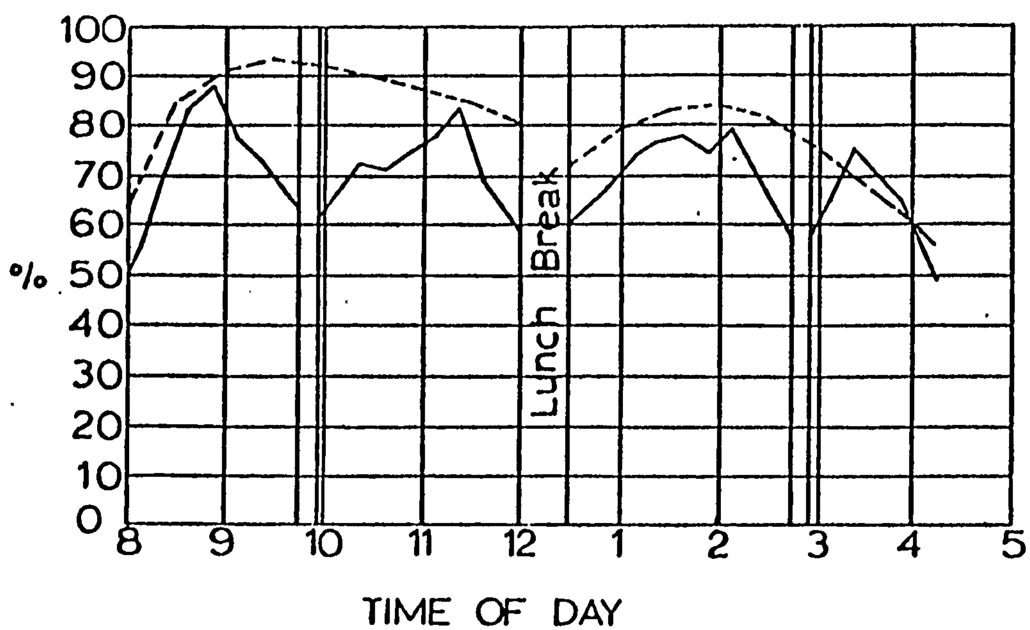
- IN THE U.S., QUALITY AND PRODUCTIVITY ARE REGARDED GENERALLY AS COMPETING RATHER THAN COMPLIMENTARY ISSUES. IT IS A CONTINUATION OF THE ADVERSARIAL RELATIONSHIP.

- DEMING STATES "YOU DON'T GET AHEAD BY MAKING PRODUCTS AND SEPARATING THE GOOD FROM THE BAD, BECAUSE THAT'S WASTEFUL".

- THERE IS A CONCISE, MATHEMATICALLY SOUND RELATIONSHIP BETWEEN PROFITABILITY AND PRODUCTIVITY. IT IS -

PROFITABILITY = PRODUCTIVITY x PRICE RECOVERY





Labour Utilisation

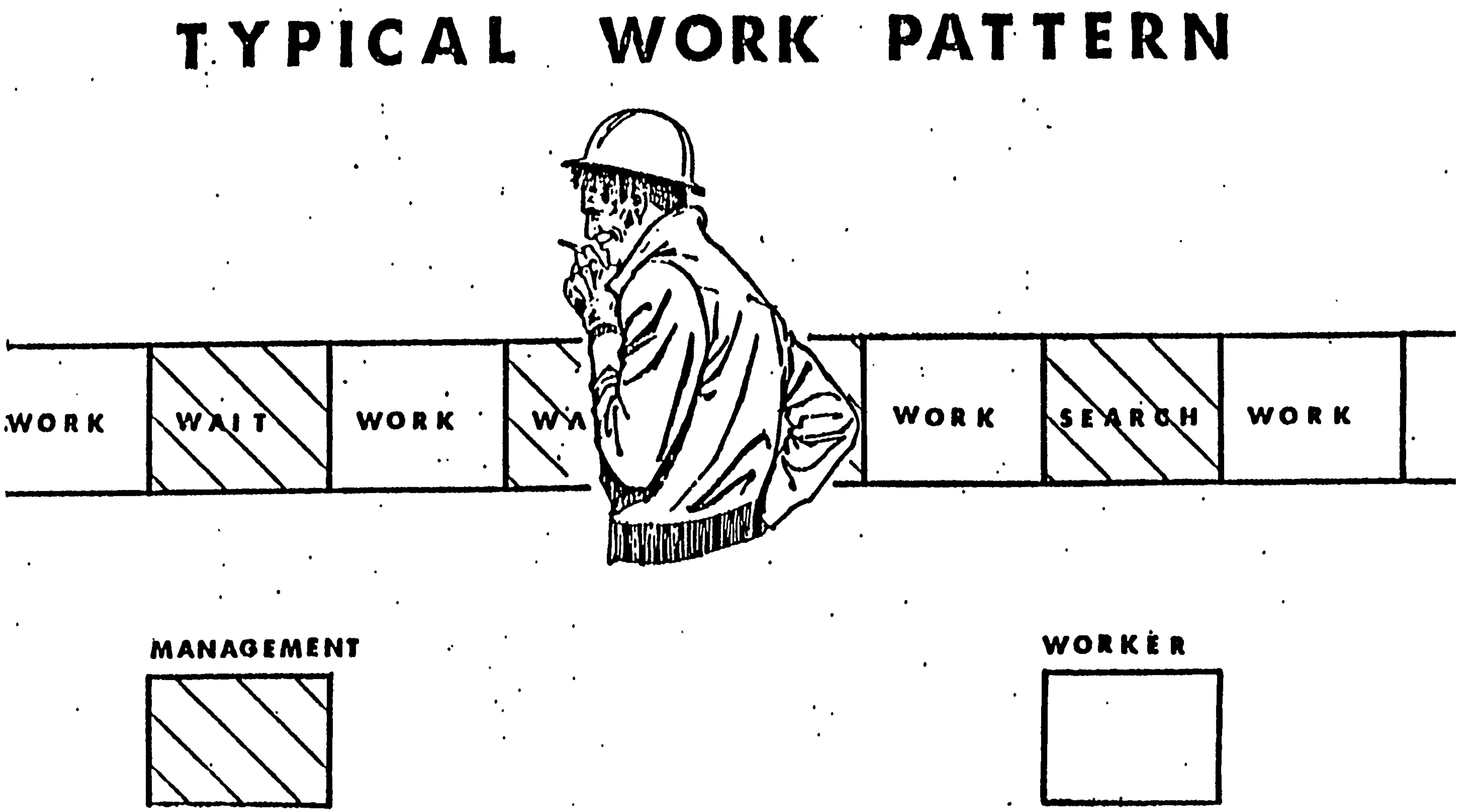

TYPICAL WORK PATTERN
WORK
WAIT
WORK
WORK
SEARCH
WORK
MANAGEMENT
WORKER

FIGURE 3

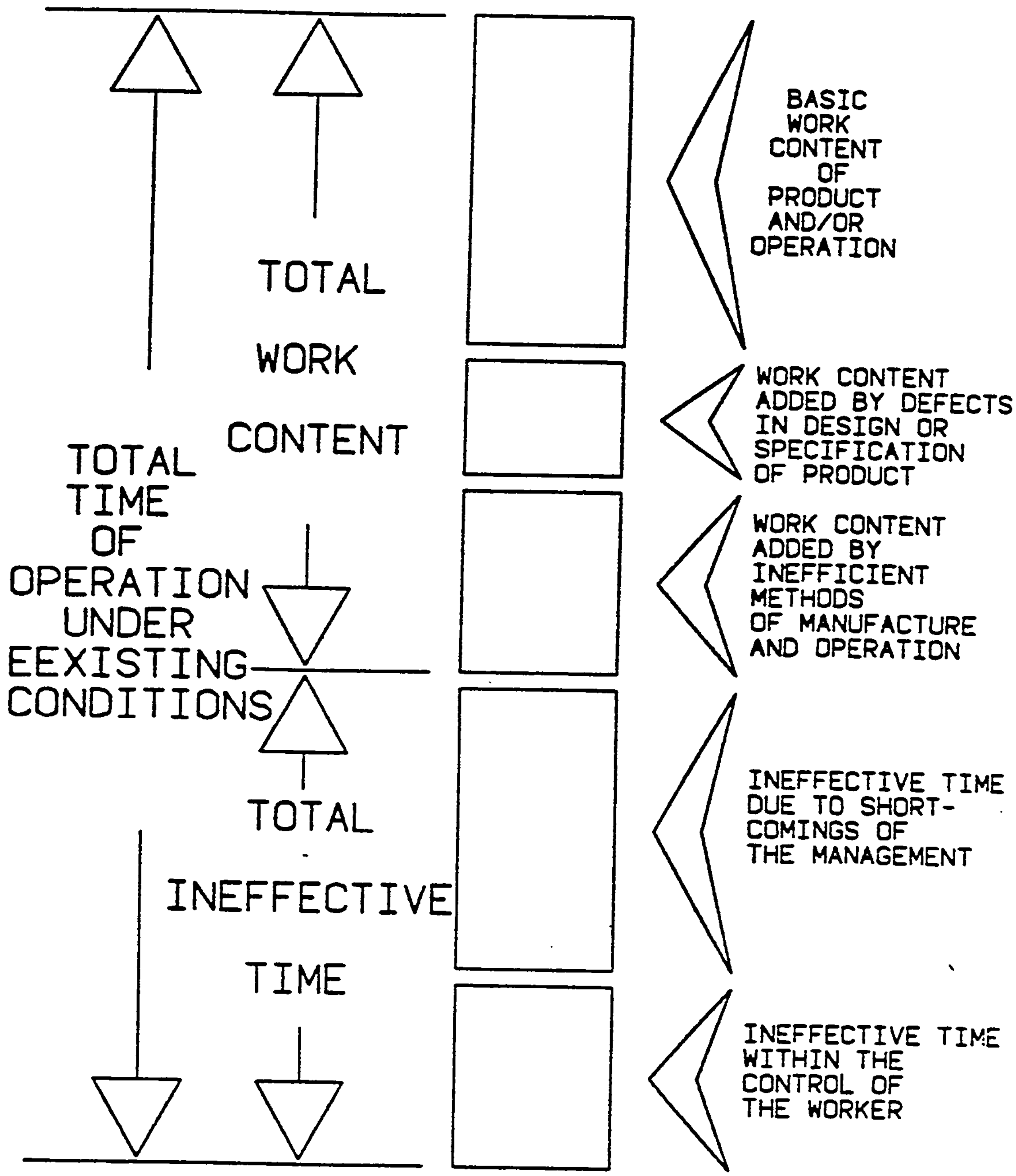


FIGURE 4 - MAKE UP OF TOTAL WORK TIME

0 THE MAJOR FACTORS WHICH INFLUENCE PRODUCTIVITY:

(A) WORKERS PERFORMANCE

THE RATIO OF THE TARGET OR MEASURED WORK CONTENT STANDARD MANHOURS TO THE ACTUAL MANHOURS TAKEN.

e.g. $$\frac{\text{80 STANDARDS MANHOURS}}{\text{100 ACTUAL MANHOURS TAKEN}} \times 100$$

= 80 PERFORMANCE

(B) WORKFORCE UTILIZATION

THE PERCENTAGE RATIO OF THE DIFFERENCE BETWEEN ATTENDANCE MANHOURS AND STOPPAGE MANHOURS TO ATTENDANCE MANHOURS.

e.g. $$\frac{\text{200 ATTENDANCE MANHOURS - 40 STOPPAGE MANHOURS}}{\text{200 ATTENDANCE MANHOURS}} \times 100$$

= 80% UTILIZATION

(C) <u>METHOD LEVEL</u>

THE PERCENTAGE RATIO OF THE PROJECTED, MEASURED OR STANDARD MANHOURS TO PERFORM THE JOB USING AN IMPROVED METHOD TO THE MEASURED OR STANDARD MANHOURS USING THE EXISTING METHOD.

e.g. $\dfrac{\text{80 STANDARD MANHOURS FOR PROJECTED METHOD}}{\text{100 STANDARD MANHOURS FOR EXISTING METHOD}}$ X 100 100

= 80% METHOD LEVEL

- FIGURE 9 SHOWS HOW THE EFFECTS Of THESE FACTORS CAN COMPOUND AND EXPLAINS HOW THE PRODUCTIVITY DIFFERENCE BETWEEN SHIPYARD ‘A’ AND SHIPYARD ‘B’ COULD OCCUR .

- IT ALSO EXPLAINS HOW AN ADVANCED SHIPYARD CAN HAVE LOW PRODUCTIVITY.

- IT IS THEREFORE CLEAR THAT IF A SHIPYARD DESIRES TO IMPROVE PRODUCTIVITY, THEY MUST FIRST DETERMINE THE VALUES OF THE PRODUCTIVITY FACTORS. THEN THEY CAN WORK ON THE LOW VALUE(S) BEFORE CONTEMPLATING CHANGE OF THE BEST. IT IS ILLOGICAL TO INVEST LARGE SUMS OF MONEY TO IMPROVE EXISTING OR BUILD NEW SHIPYARD FACILITIES IF EXISTING PERFORMANCE AND UTILIZATION ARE LOW.

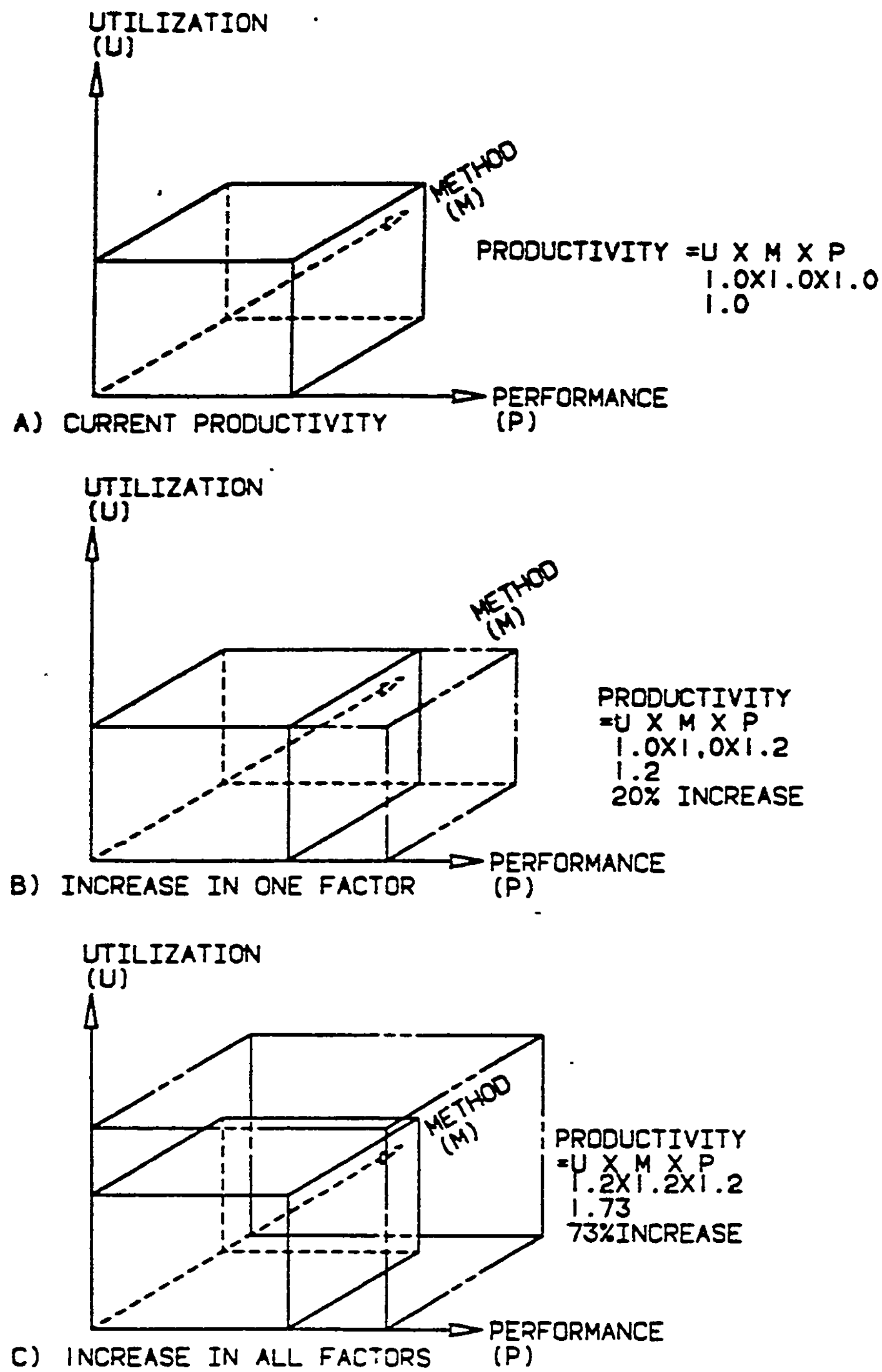


FIGURE 9 - PRODUCTIVITY SPACE

- FACTORS THAT MIGHT IMPACT PRODUCTIVITY:

  - FACILITIES
  - COMPUTER SYSTEMS
  - UNIONS
  - MANAGEMENT

° HOW TO IMPROVE WORK ORGANIZATION

- STANDARDIZATION
- SIMPLIFICATION
- SPECIALIZATION

INCREASED STANDARDIZATION WILL MAKE IT POSSIBLE TO IDENTIFY AND SET UP WORK STATIONS WITH LIMITED PRODUCT VARIETY.

SIMPLIFICATION OF INTERIM PRODUCTS WILL LEAD TO REDUCED WORK CONTENT AND EASIER PRODUCTION.

WITH SIMPLIFIED PRODUCTION, INCREASED SPECIALIZATION OF PROCESSES AND EQUIPMENT WILL LEAD TO GREATER EFFICIENCY.

o HIGHLY PRODUCTIVE SHIPYARDS ARE CHARACTERISTICS BY:

- CLEARLY DEFINED OBJECTIVES AND POLICY
- SHORT BUILD CYCLES
- OVERLAPPING OF STRUCTURE AND OUFIT WORK
- MANAGEMENT AWARENESS OF PRODUCTIVITY MEASUREMENTS

o TO ACHIEVE HIGH PRODUCTIVITY:

- FIRST, DEVELOP A SHIPBUILDING STRATEGY
- SECOND, ESTABLISH INTEGRATED PLANNING AND METHODS ORGANIZATION

o IDENTIFIED NUMBER OF COMMON CORE TECHNOLOGY ITEMS

COMPETITION

AT BEGINNING OF
COMPETITION

U.S. SHIPBUILDING FACTS

CURRENT SITUATION

MOST U.S. SHIPBUILDERS AGREE THAT THERE IS A PRODUCTIVITY GAP BETWEEN U.S. AND BEST IN THE WORLD.

SOME IMPORTANT SHIPBUILDING TOP MANAGEMENT DO NOT BELIEVE IT OR BELIEVE IT IS BECAUSE OF SPECIAL TREATMENT BY OTHER COUNTRIES GOVERNMENT, THAT IS, SUBSIDIES, AND THEY LOOK TO THE U.S. GOVERNMENT TO HELP THEM.

THIS POSITION IS BASED ON THE BELIEF THAT THE POLITICAL SOLUTION OFFERS THE BEST HOPE FOR THE SURVIVAL OF THE LARGE U.S. SHIPBUILDERS. THAT IS, U.S. NAVY MUST HAVE A DEFENSE BUILD UP CAPABILITY AND THE GOVERNMENT CANNOT AFFORD TO LET ANY MORE LARGE SHIPYARDS CLOSE. THEY LOOK TO THEIR SENATORS AND CONGRESSMEN TO SAVE THEM.

OTHER STILL BELIEVE IT IS BECAUSE BEST IN WORLD SHIPBUILDERS BUILD SERIES SHIPS, EVEN THOUGH THIS MYTH HAS BEEN DISPELLED.

U.S. SHIPBUILDING FACTS

CURRENT SITUATION (CONTINUED)

THE SIX LARGE SHIPYARDS BELIEVE THAT THE ONLY WAY THEY CAN COMPETE IN INTERNATIONAL SHIPBUILDING IS FOR U.S. GOVERNMENT TO GIVE SUBSIDIES TO COVER DIFFERENCE IN COST AT LEAST FOR A START UP DURATION.

OTHERS BELIEVE THAT U.S. GOVERNMENT MUST UNDERTAKE A BUILD PROGRAM OF COMMERCIAL SHIPS FOR U.S. SHIPYARDS TO GIVE THEM THE NECESSARY DEMAND AND THEREFORE OPPORTUNITY TO IMPROVE TO WORLD CLASS.

U.S. GOVERNMENT HAS TRIED THIS IN PART THROUGH THE CURRENT MILITARY SEALIFT PROGRAM AND THE PROPOSED FUTURE MID TERM FAST SEALIFT SHIP PROGRAM.

EMPLOYEMENT IN SHIPYARDS IS APPROXIMATELY 73,000 DOWN FROM 120,000 IN 1985. PLANNED NAVY SHIPBUILDING WILL ONLY SUPPORT 23,000 BY YEAR 2000.

U.S. SHIPBUILDING FACTS

CURRENT SITUATION (CONTINUED)

AVERAGE EMPLOYMENT IN U.S. LARGE SHIPYARDS RANGES FROM A MINIMUM OF 3,500 TO 19,000. WORLD CLASS LARGE FORIEGN SHIPYARDS AVERAGE 1,200. HOWEVER, ONE KOREAN SHIPYARD EMPLOYS 10,000 SHIPBUILDERS, BUT THEY DELIVER UP TO 40 SHIPS PER YEAR.

THROUGHPUT OF WORLD CLASS LARGE FORIEGN SHIPYARDS IS 4 TO SIX SHIPS PER YEAR. THIS IS DONE WITH SHORT BUILD CYCLES

A ONE SHIP A YEAR SHIPYARD SHOULD HAVE NO MORE THAN 300 EMPLOYEES.

THERE IS NO SUCCESSFULL DUAL PURPOSE SHIPYARD IN THE WORLD. EVEN THE JAPANESE DEFENSE SHIPYARDS ARE NOT AS PRODUCTIVE AS THEIR OTHER COMMERCIAL ONLY SHIPYARDS.

U.S SHIPBUILDERS WANT TO BE DUAL PURPOSE. THAT IS NONE OF THEM WANT **TO CUT THE LIFELINE TO THE GOVERNMENT.**

U.S. SHIPBUILDING

- EARLY SUCCESS IN OBTAINING COMMERCIAL ORDERS HAS BOGGED DOWN IN TITLE XI APPROVAL
- NEWPORT NEWS ACKNOWLEDGES THAT THEY ARE NOT COMPETITIVE AND ARE TAKING ORDERS TO SUSTAIN MANNING LEVEL, NOT TO MAKE A PROFIT
- AVONDALE'S OBJECTIVE IS TO CAPTURE SHARE OF WORLD MARKET AND TO MAKE A PROFIT
- AVONDALE'S RUSSIAN TANKER, BENDER'S REEFER SHIP AND ATLANTIC MARINE'S CHEMICAL TANKER PROJECTS ALL APPEAR DEAD
- OTHER U.S. SHIPBUILDERS ARE STILL IN NEGOTIATION WITH POTENTIAL FOREIGN AND U.S. CUSTOMERS

WORLD SHIPBUILDING

- PRICES ARE STILL LOWER THAT COST IN MOST COUNTRIES
- ORDERS IN 1995 ARE LESS THAN ORDERS IN 1994
- TOTAL DEADWEIGHT ON ORDER IS ABOUT 25 MILLION TDWT
- WORLD SHIPBUILDING CAPACITY IS OVER 30 MILLION TDWT
- TOTAL NUMBER OF SHIPS ON ORDER IS ABOUT 700
- KOREA HAS HAD THE MOST GAIN IN TERMS OF TDWT
- KOREA HAS TAKEN LEAD FROM JAPAN IN TERMS OF TDWT BUT JAPAN STILL HAS SIGNIFICANT LEAD IN TERMS OF NUMBER OF SHIPS

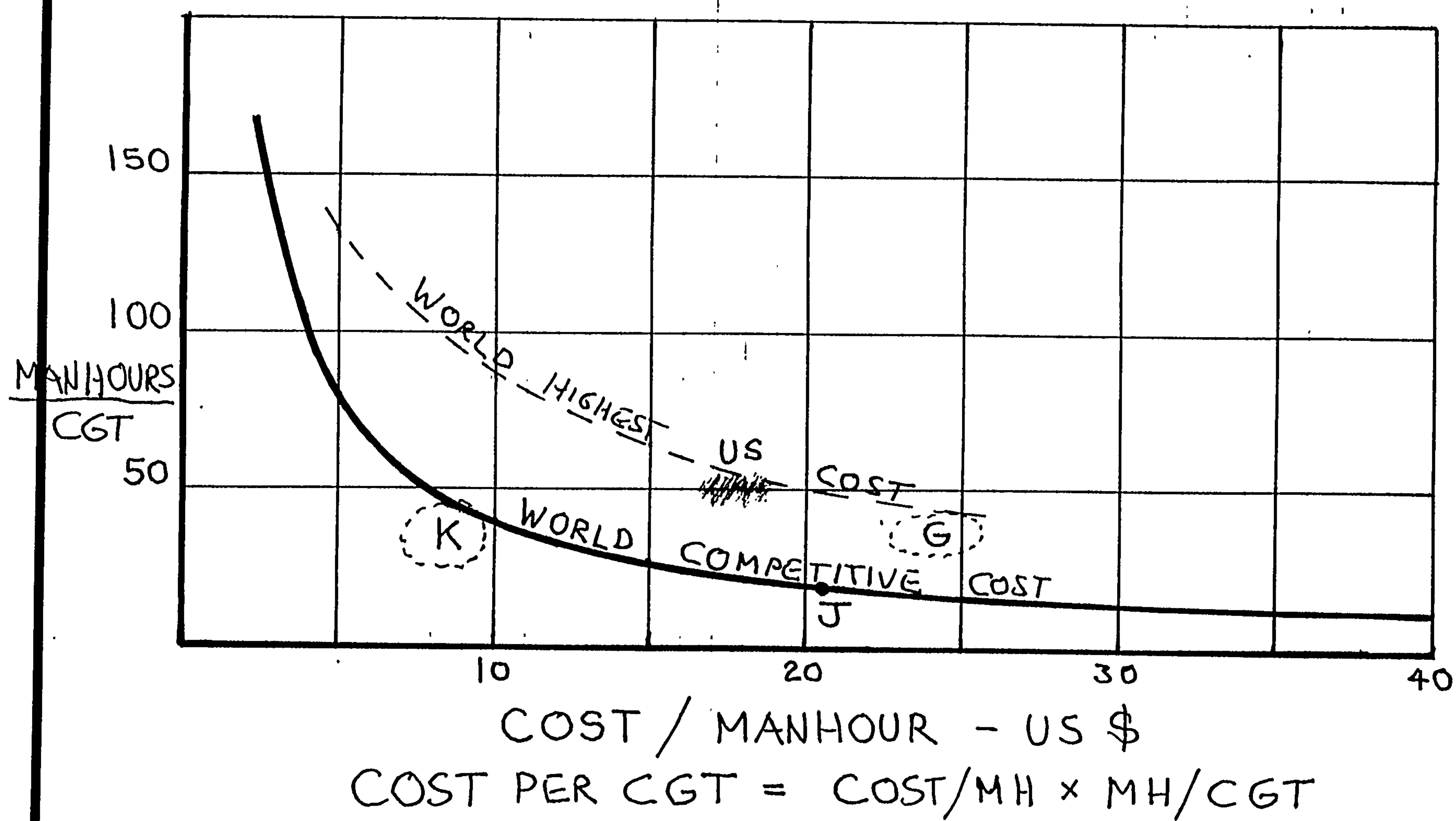
WORLD SHIPBUILDING (Continued)

- EUROPE HAS LOST 30% SINCE 1991

- THERE IS FIERCE COMPETITION IN THE CONTAINER SHIP MARKET FOR ALL SIZES. JAPAN HAS RECENTLY BOOKED 16 LARGE CONTAINER SHIPS. SMALLER SHIPS ARE SHARED BY POLAND AND GERMANY

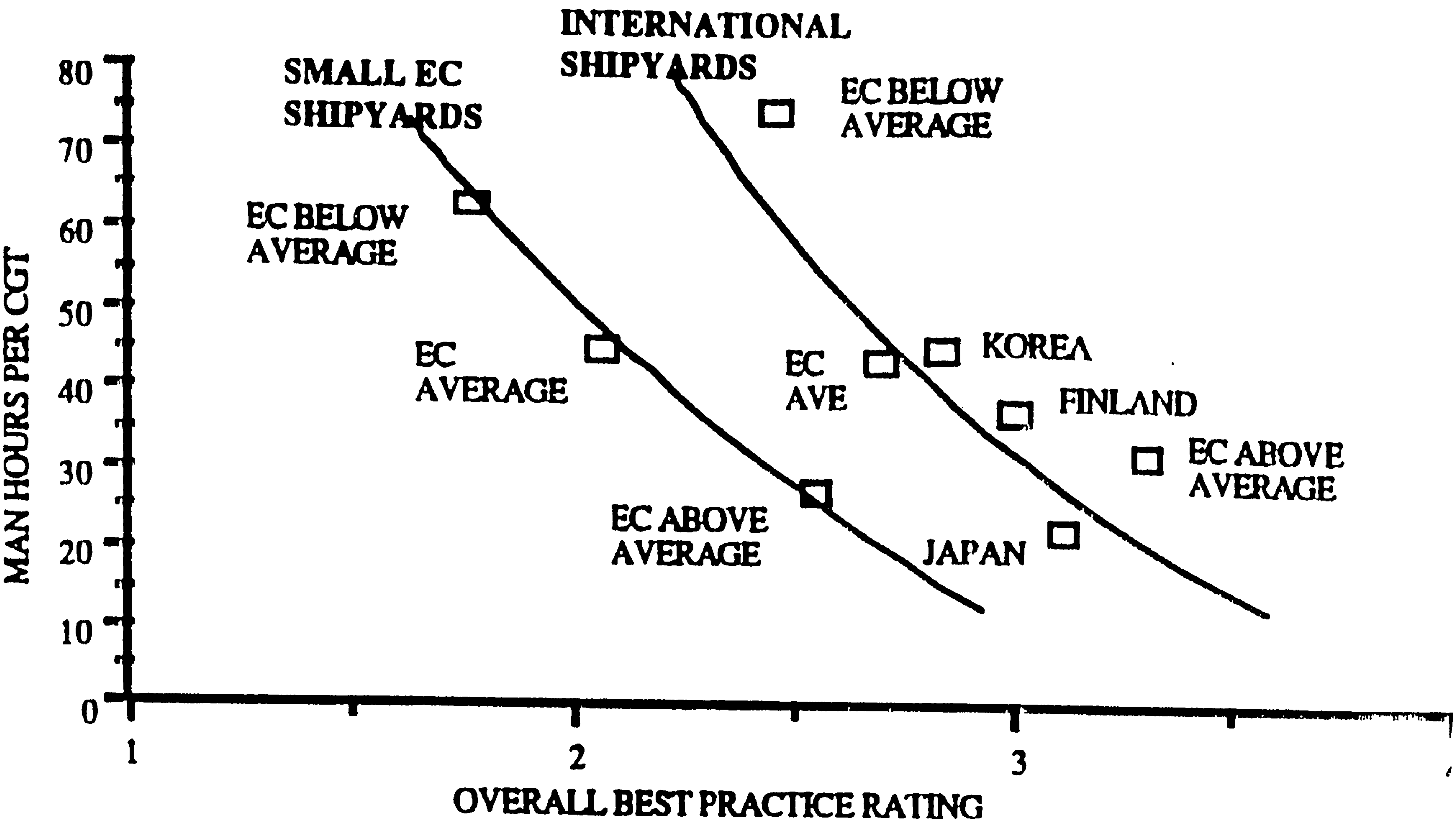
- BULK CARRIER MARKET STILL APPEARS STRONG

- INDONESIAN SHIPBUILDERS ARE CAPTURING SOME ORDERS, INCLUDING REEFERS, A TRADITIONAL EUROPEAN MARKET



150
100
50
MANHOURS / CGT
WORLD HIGHEST US COST
WORLD COMPETITIVE COST
K
G
J
10
20
30
40
COST / MANHOUR - US $
COST PER CGT = COST/MH × MH/CGT

Best Practice/Performance Correlation



SHIPYARD COMPETITIVENESS

COMPENSATED GROSS TONNAGE

COMPARING SHIPS ON THE BASIS OF THEIR GROSS TONNAGES IS NOT USEFUL BECAUSE THE WORK CONTENT OF DIFFERENT SHIP TYPES AND SIZES IS NOT TAKEN INTO ACCOUNT. TO OVERCOME THIS THE CONCEPT OF COMPENSATED GROSS TONNAGE WAS DEVELOPED. THAT IS THE GROSS TONNAGE FOR A SHIP WOULD BE COMPENSATED TO TAKE ACCOUNT OF THESE IMPORTANT DIFFERENCES. A COMPLETE SET OF COMPENSATION FACTORS HAS BEEN IN DEVELOPEMENT SINCE 1967 AND ACCEPTED BY THE OECD 1984.

UNFORTUNATELY NO COEFFICIENTS HAVE BEEN PUBLISHED FOR WARSHIPS. THIS MAKES IT DIFFICULT, BUT NOT IMPOSSIBLE FOR U.S. SHIPYARDS TO USE THE APPROACH TO COMPARE THEIR CURRENT PERFORMANCE WITH MILITARY SHIPS TO THE WORLD COMMERCIAL SHIPBUILDING MARKET

SHIPYARD COMPETITIVENESS

THERE IS NO UNIVERSALLY ACCEPTED DEFINITION OF COMPETITIVENESS. KPMG PEAT MARWICK, IN THEIR STUDY OF THE COMPETITIVENESS OF EEC SHIPYARDS, DEFINE IT AS "THE ABILITY TO WIN AND EXECUTE SHIPBUILDING ORDERS IN OPEN COMPETITION AND STAY IN BUSINESS." I WOULD ADD

PROFITABLY.

A MEASURE THAT HAS BEEN ACCEPTED BY OECD TO COMPARE SHIPBUILDING PRODUCTIVITY IS MANHOURS/COMPENSATED GROSS TONNAGE (CGT). THIS CAN BE MADE INTO A QUASI COMPETITIVENESS MEASURE BY MULTIPLYING THE MANHOURS BY THE COUNTRY SHIPYARD LABOR RATE IN U.S. DOLLARS

THIS MEASURE FOR A SHIPYARD CAN BE PLOTTED ON CONSTANT COST CURVES AND COMPARED TO OTHER WORLD SHIPBUILDERS

SP-4 COMPARATIVE GLOBAL SHIPBUILDING TECHNOLOGY STUDIES

PRODUCTIVITY VERSUS TECHNOLOGY (Continued)

JUSTIFICATION OF POSITION

GENERAL MOTORS CHOSE TECHNOLOGY ROUTE AND SPENT BILLIONS ON FULLY AUTOMATED FACTORY. RESULTS HAVE BEEN DISAPPOINTING.

FORD CHOSE TO IMPROVE THE DESIGN AND BUILD PROCESS. THIS RESULTED IN THE TAURUS TEAM AND A VERY SUCCESSFULL CAR.

SP-4 COMPARATIVE GLOBAL SHIPBUILDING TECHNOLOGY STUDIES

PRODUCTIVITY VERSUS TECHNOLOGY (Continued)

THERE IS A LOT OF ROOM FOR IMPROVEMENT WITHOUT INVESTMENT IN "ADVANCED TECHNOLOGY."

IN FACT, EXPERIENCE HAS CLEARLY SHOWN THAT THE INTRODUCTION OF ADVANCED TECHNOLOGY INTO A FACILITY THAT IS NOT OPERATING AT ITS BEST WITH WHAT IT HAS, WILL NOT REAP THE FULL BENEFIT OF THE NEW TECHNOLOGY.

SO FIRST IT IS NECESSARY TO MAKE ALL THE IMPROVEMENTS YOU CAN WITH WHAT YOU HAVE AND THEN DECIDE WHAT ADVANCED TECHNOLOGY YOU NEED TO PUT YOU AHEAD OF THE COMPETITION AND TO MAINTAIN A COMPETITIVE ADVANTAGE.

SP-4 COMPARATIVE GLOBAL SHIPBUILDING TECHNOLOGY STUDIES

PRODUCTIVITY VERSUS TECHNOLOGY (Continued)

TECHNOLOGY IS ONLY ONE PART OF THE PRODUCTIVITY EQUATION. PRODUCTIVITY IS INFLUENCED BY A COMBINATION OF THE FOLLOWING FACTORS:

- TECHNOLOGY
- FACILITIES
- PLANNING
- MANAGEMENT COMPETENCE
- WORK ORGANIZATION
- WORK PRACTICES
- WORKER MOTIVATION
- WORKER SKILLS

SP-4 COMPARATIVE GLOBAL SHIPBUILDING TECHNOLOGY STUDIES

PRODUCTIVITY VERSUS TECHNOLOGY

EUROPE ADVANCED CAD/CAM, INTEGRATED SYSTEMS

1800 PRODUCTION WORKERS BUILD 4 VLCCS PER YEAR

JAPAN ADVANCED CAD/CAM, STANDARD PRACTICES AND HIGHLY SKILLED WORKERS

1400 PRODUCTION WORKERS BUILD 6 VLCCS PER YEAR

850 PRODUCTION WORKERS BUILD 2 1/2 VLCCS OR 8 140,000 TDWT TANKERS PER YEAR

ALTHOUGH LARGE BLOCK AND LARGE CRANE TECHNOLOGY DOES IMPROVE PRODUCTIVITY, THE MAIN REASON FOR IT IS TO INCREASE THROUGHPUT BY MINIMIZING BERTH ERECTION TIME.

SP-4 COMPARATIVE GLOBAL SHIPBUILDING TECHNOLOGY STUDIES

TECHNOLOGY COMPARISON

CATEGORY	1978			1993/4		
	US	FOREIGN		US	FOREIGN	
STEELWORK PRODUCTION	2.3	2.9	(.6)	2.9	3.5	(.6)
OUTFIT PRODUCTION	2.6	2.5	(-.1)	3.3	3.7	(.4)
OTHER PRE-ERECTION	2.0	2.8	(.8)	3.8	4.0	(.3)
SHIP CONSTRUCTION	2.5	2.9	(.4)	3.2	4.0	(.8)
LAYOUT & MATERIAL HANDLING	2.5	3.0	(.5)	2.9	3.3	(.4)
DESIGN AND ENGINEERING	3.0	3.2	(.2)	3.4	4.3	(.9)
ORGANIZATION & OPERATING	3.0	3.0	(0)	4.0	4.7	(.7)
AVERAGE	2.5	2.9	(.4)	3.4	4.0	(.6)

SP-4 COMPARATIVE GLOBAL SHIPBUILDING TECHNOLOGY STUDIES

TECHNOLOGY LEVELS (CONTINUED)

LEVEL 4 BEST 1980 SHIPBUILDING PRACTICE WITH CONTINUOUS IMPROVEMENT. LARGE BLOCK CONSTRUCTION WITH ADVANCED OUTFITTING AND SHIP VIRTUALLY COMPLETE AT LAUNCH.

LEVEL 5 STATE OF THE ART SHIPBUILDING IN 1990. DEVELOPED FROM LEVEL 4 THROUGH AUTOMATION, INTEGRATION OF OPERATING SYSTEMS, EFFECTIVE USE OF CAD, COMPUTER AIDED MATERIAL PLANNING AND IMPROVED QUALITY THROUGH COMPLETE USE OF ACCURACY CONTROL

SP-4 COMPARATIVE GLOBAL SHIPBUILDING TECHNOLOGY STUDIES

TECHNOLOGY LEVELS

LEVEL 1	1960 SHIPBUILDING PRACTICE. MULTIPLE BERTHS, SMALL CRANES, ONBOARD OUTFITTING AFTER LAUNCH. MANUAL OPERATING SYSTEMS
LEVEL 2	GOOD 1970 SHIPBUILDING PRACTICE. MODERNIZED FACILITIES, FEWER BERTHS USED OR BUILDING DOCK, LARGER CRANES AND PRE-OUTFITTING. SOME COMPUTER BASED OPERATING SYSTEMS.
LEVEL 3	GOOD 1980 SHIPBUILDING PRACTICE. NEW OR FULLY RE-DEVELOPED SHIPYARDS WITH LARGE CAPACITY CRANES, SINGLE DOCK WITH SOME ENVIRONMENTAL PROTECTION. LARGE DEGREE OF MECHANIZATION AND EXTENSIVE USE OF COMPUTERS

Figure 2 Total No. Of Ships On Order

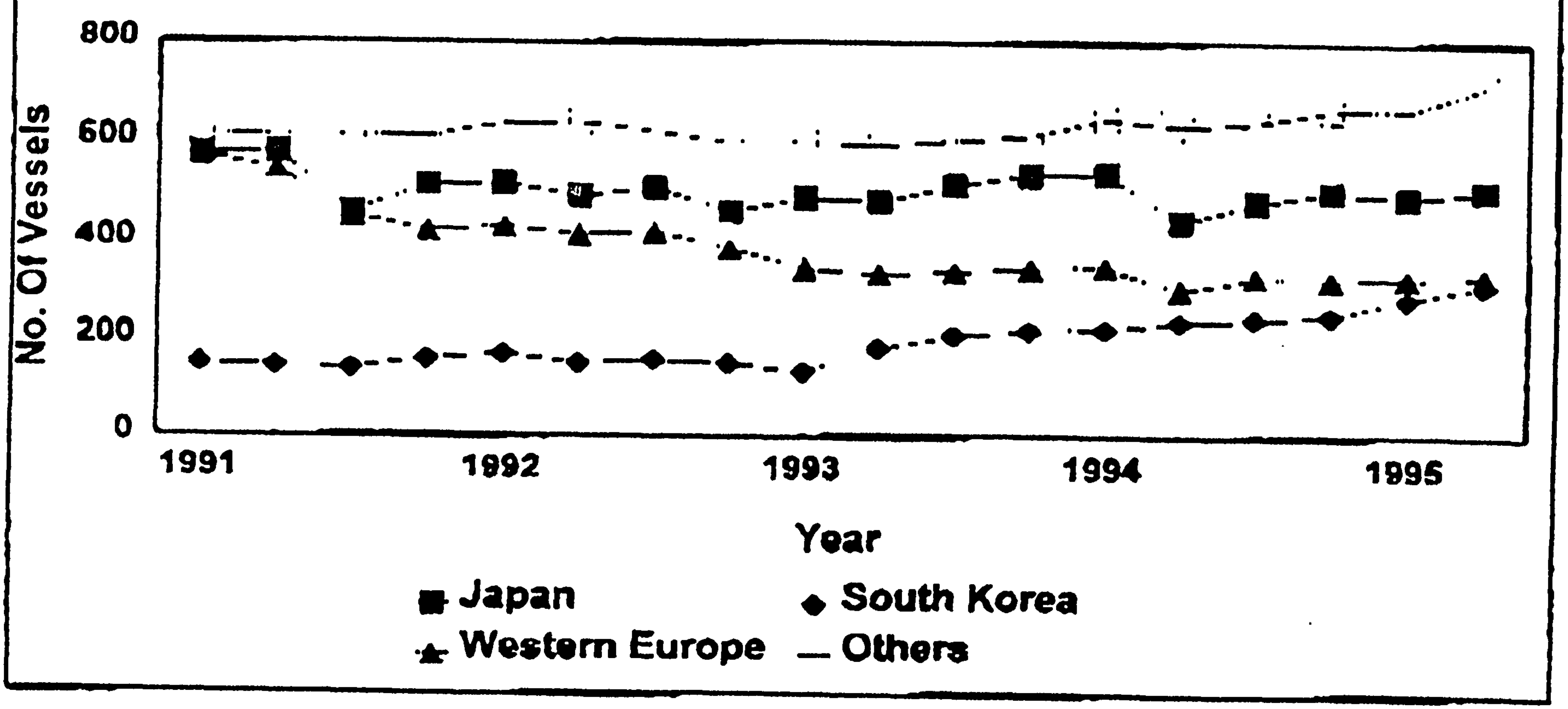
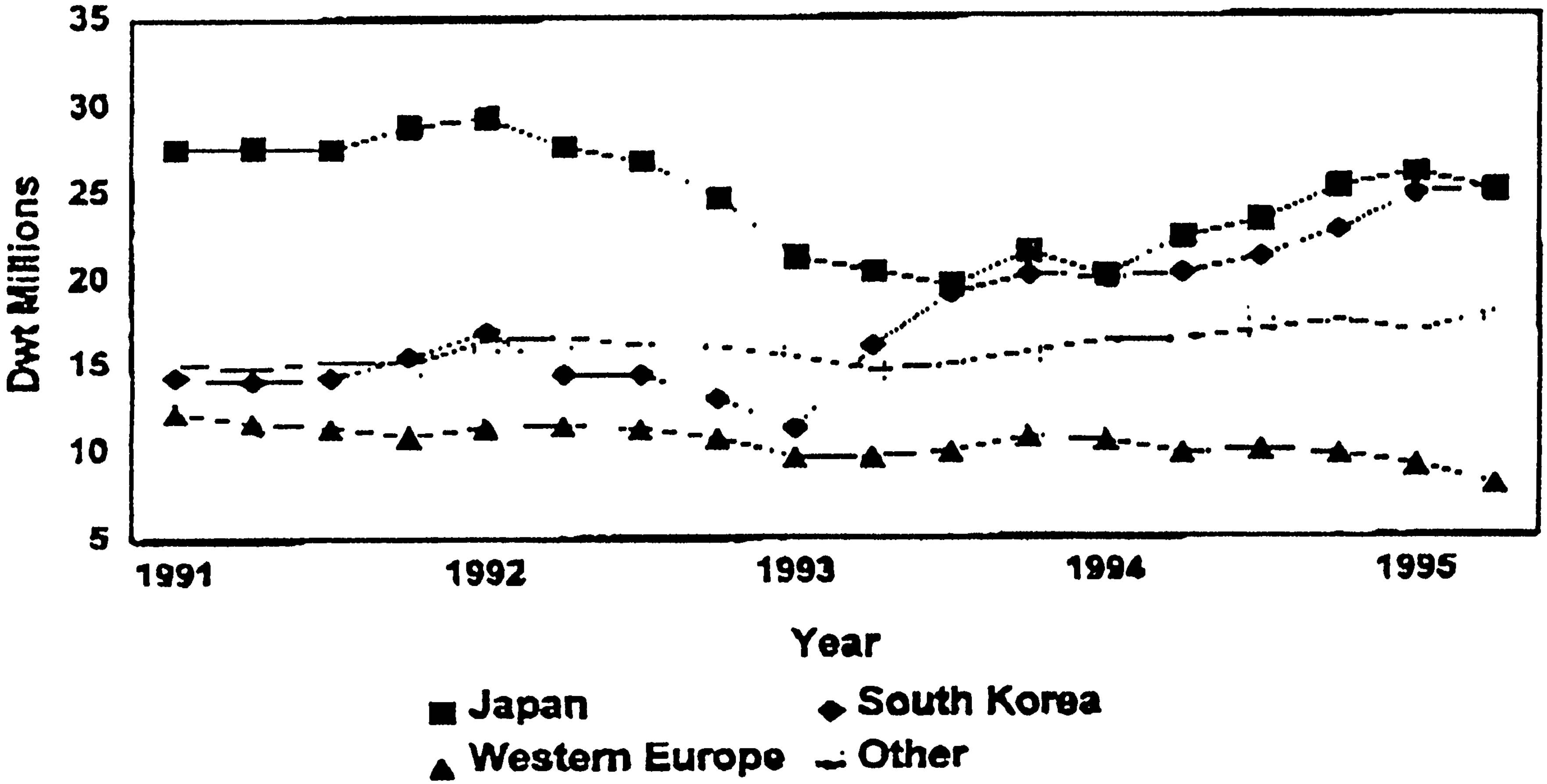


Figure 1 Total Deadweight On Order



SHIPBUILDING MARKET SHARE

[A] SHARE BY DWT ON ORDER

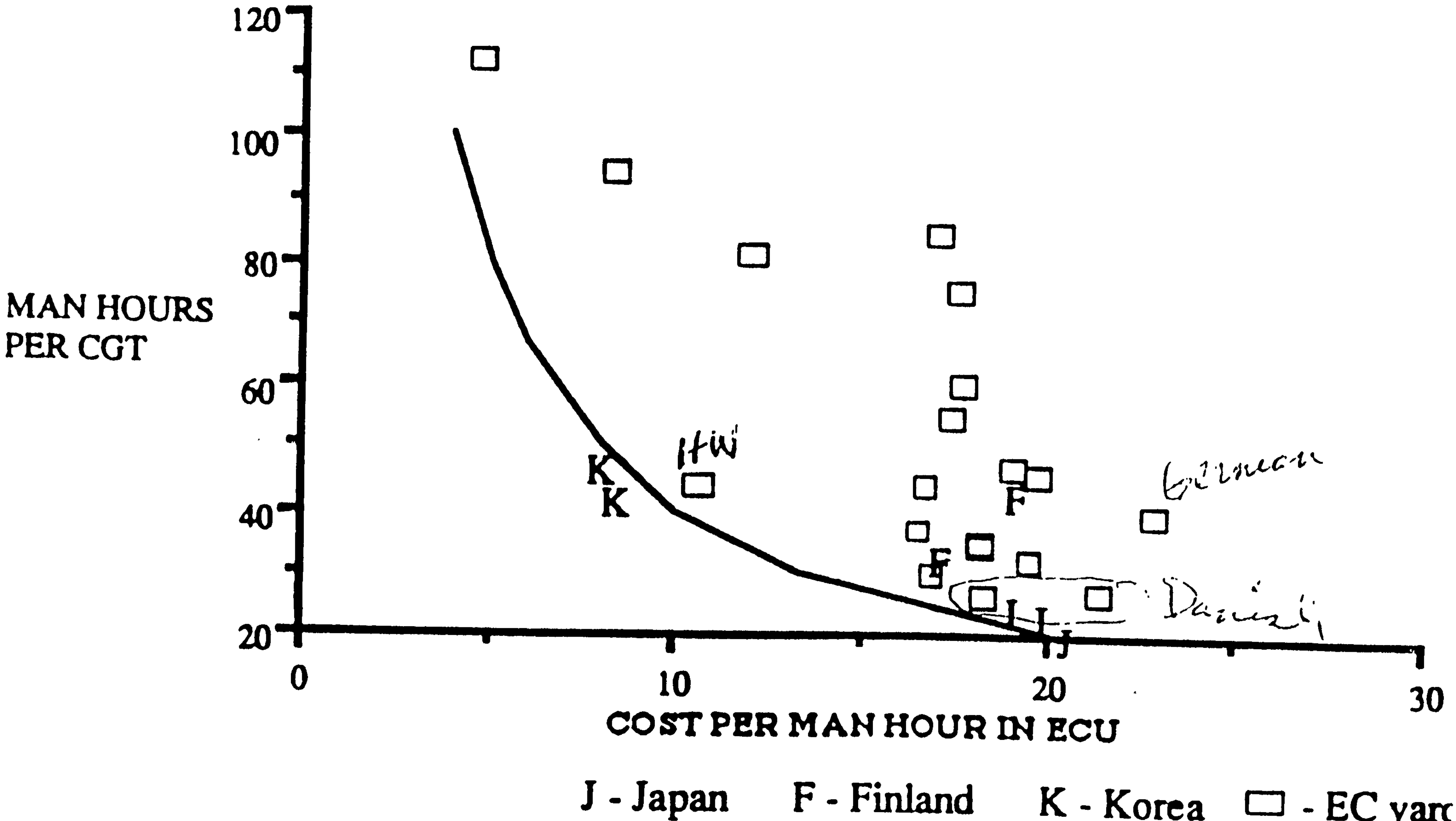
SHIPBUILDING BLOCK	MARKET SHARE 1991	1995
JAPAN	40%	33%
SOUTH KOREA	21%	33%
WESTERN EUROPE	18%	11%
OTHERS	22%	24%

[B] SHARE BY NUMBER OF SHIPS ON ORDER

JAPAN	30%	27%
SOUTH KOREA	8%	17%
WESTERN EUROPE	30%	18%
OTHERS	32%	38%

SOURCE: A&P APPLEDORE USING DATA FROM FAIRPLAY SHIP ON ORDER

Shipyard labour cost comparisons



DESIGN AND BUILDING CYCLE TIME

SHORT DESIGN AND BUILDING CYCLE TIMES ARE DIRECTLY RELATED TO HIGH ANNUAL OUTPUT, SUCH AS:

4 TO 6 VLCCS
6 TO 8 140,000 TDWT TANKERS AND/OR BULK CARRIERS
4 TO 6 CONTAINERSHIPS
OR
8 PRODUCT TANKERS

SHORT DESIGN AND BUILDING CYCLES ARE ONLY POSSIBLE WITH SUFFICIANT AND CONTINUOUS DEMAND FOR SHIPS.
FOR EXAMPLE: 4 MONTH BERTH TIMES REQUIRE 3 OR MORE SHIP COMPLETIONS PER YEAR

CONCLUSIONS

INSTEAD OF NARROWING THE TECHNOLOGY GAP BETWEEN U.S. AND FOREIGN SHIPYARDS IT HAS OPENED SLIGHTLY.

THE BEST U.S. SHIPYARD TECHNOLOGY LEVEL IS A FULL LEVEL BELOW THE BEST FOREIGN SHIPYARD.

THIS MAY BE BECAUSE U.S. SHIPYARDS TRY TO MAINTAIN FLEXIBILITY IN TYPES OF SHIPS BUILT WHEREAS THE FOREIGN SHIPYARDS ARE MORE FOCUSED ON ONE OR TWO TYPES.

WHEREAS U.S. SHIPYARDS HAVE REDUCED THE GAP BY HALF FOR C - OTHER PRE-ERECTION ACTIVITIES WHICH WAS THE MAJOR DIFFERENCE IN 1978 THE GAP FOR THREE OTHER CATEGORIES HAVE INCREASED, NAMELY:

B - OUTFIT PRODUCTION AND STORES	FROM -0.1 TO .45
D - SHIP CONSTRUCTION/OUTFIT INSTALLATION	FROM .4 TO .8
G - DESIGN, DRAFTING AND LOFTING	FROM .2 TO .9

TABLE I
PRODUCTION MANHOURS

SHIP TYPE	CGT	PRODUCTION MANHOURS EUROPE	PRODUCTION MANHOURS JAPAN
VLCC	37,500	1,185,000	1,030,000
Product Tanker	21,000	475,000	395,000
Bulk Carrier	31,200	643,000	465,000
Container Ship 4,400 TFEU	35,000	765,000	
Container Ship 1,880 TFEU	19,500	434,000	
Ferry	29,000	1,250,000	

TABLE II
CONSTRUCTION TIME IN MONTHS(Keel Laying to Delivery)

SHIP TYPE	EUROPE	DENMARK	JAPAN	USA
VLCC	17	5	9	
Product Tanker	13		8	20
Bulk Carrier	14		8	
Container Ship 4,400 TFEU	17	8	9	
Container Ship 1,880 TFEU	12	7		24
Ferry	13			

TABLE III
DESIGN MANHOURS

SHIP TYPE	DESIGN MANHOURS (Europe)
VLCC	75,500 Single Hull 102,00 Double Hull
Product Tanker	36,000
Bulk Carrier	48,000
Container Ship 4,400 TFEU	72,500
Container Ship 1,880 TFEU	42,500
Ferry	226,000

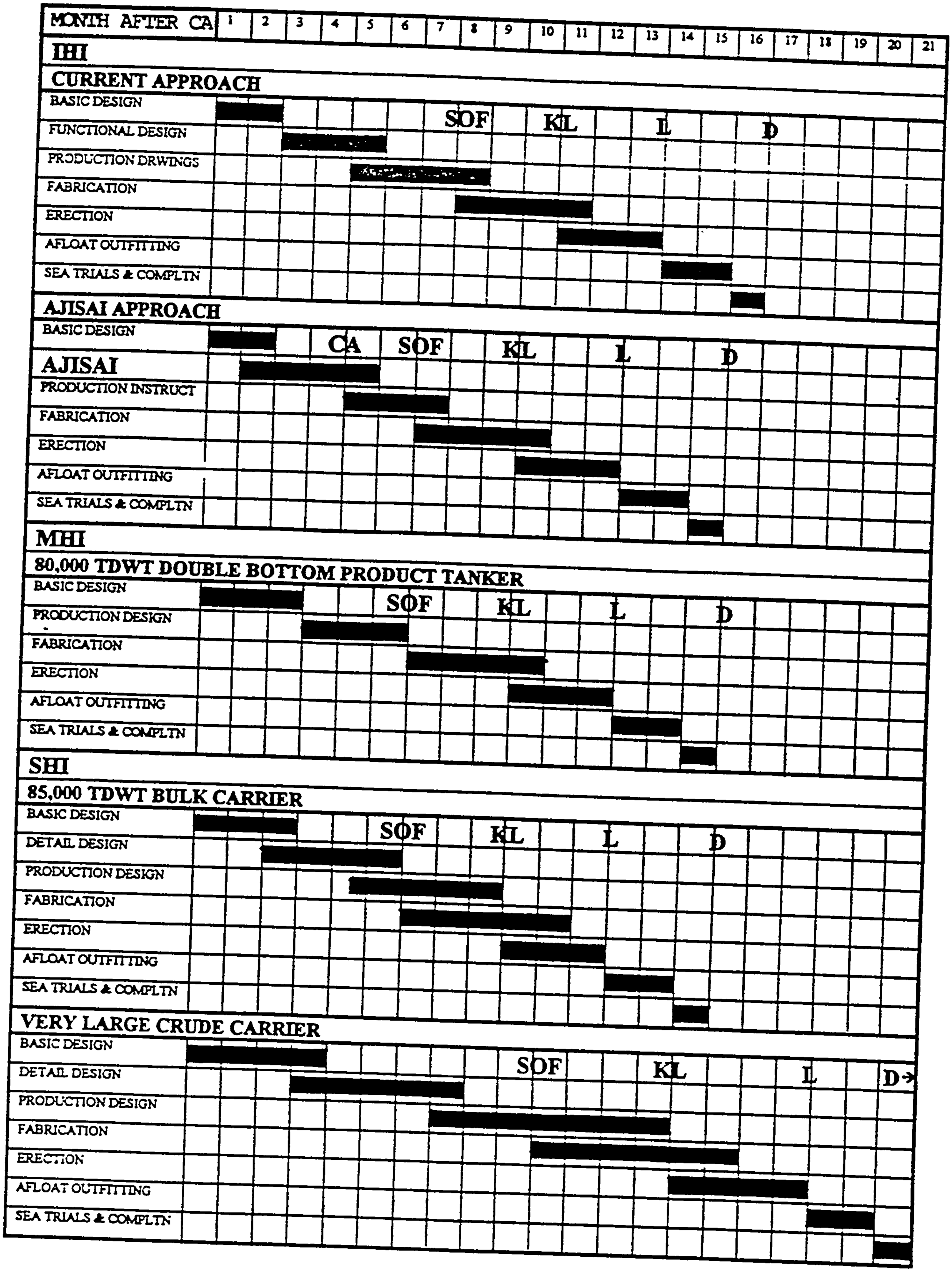


FIGURE 7.1.1 - TYPICAL JAPANESE DESIGN AND BUILD SCHEDULES

DESIGN AND BUILDING CYCLE TIME (Cont)

CONSTRUCTION TIME - MONTHS (KEEL LAYING TO DELIVERY)

SHIP TYPE	EUROPE	DENMARK	JAPAN	U.S.A.
VLCC	17	5	9	
PRODUCT TANKER	13		8	20
BULK CARRIER	14		8	
CONTAINERSHIP (4400)	17	~~8~~ 5	9	
CONTAINERSHIP (1880)	12	7		24

CONCLUSIONS (Continued)

TECHNOLOGY IS ONLY ONE OF MANY FACTORS INFLUENCING PRODUCTIVITY, WHICH, IN TURN, IS ONLY ONE OF MANY FACTORS INFLUENCING COMPETITIVENESS.

SHORT DESIGN AND BUILD CYCLE TIMES CAN ONLY BE ACHIEVED WITH A CORRESPONDING HIGH AND CONTINUOUS THROUGHPUT.

THERE MAY BE A SHIPYARD THROUGHPUT BELOW WHICH IT IS IMPOSSIBLE TO BE INTERNATI0NALL COMPETITIVE.

EXPERIENCE IN OTHER SUCCESSFUL SHIPBUILDING COUNTRIES SUGGEST THAT IT MAY NOT BE POSSIBLE, TO ACHIEVE INTERNATIONAL COMMERCIAL SHIPBUILDING COMPETITIVENESS IN A DUAL PURPOSE SHIPYARD

SHORT DELIVERY TIMES AND PRODUCTIVITY

OBJECTIVE

Determine how foreign shipbuilders design and build ships in much shorter time and fewer man-hours and to report them for review and use by U.S. shipbuilders.

BACKGROUND

The short design and build times for foreign shipbuilders such as Odense Steel Shipyard in Denmark, Bremer Vulcan in Germany and most of the Japanese shipbuilders are well known to U.S. shipbuilders. Information on this aspect of competitiveness has been documented in many reports (1, *2, 3 & 4).* How can the foreign shipbuilders accomplish this and the U.S. shipbuilders apparently cannot?

Also, and perhaps part of the answer to the above question how can foreign shipbuilders design and build the ship in significantly fewer man-hours, sometimes as much as half, than U.S. shipbuilders?

To answer both these questions it is first necessary to dispel the myths and to make sure that we are comparing apples and apples. However, it is not expected that these answers will show that the facts that the questions are based on are incorrect, but rather that they will clarify many areas of confusion, such as, is the 12 month schedule from Contract Award to Delivery or from Keel Laying to Delivery, or is Construction Time from Start of Fabrication or Keel Laying. AlsO how is extent of sub contracting taken into account in the stated Production man-hours to build a ship in dfferent shipyards.

These problems are not new and others have attempted to address them (5 & 6). In it's 1992 report to the Committee Of EEC Shipbuilders Association (5), Arthur Andersen cautioned,

> *"It is important to note that our study has disclosed that the shipyard which prepared our cost estimates used different accounting and estimating systems; had differing perceptions of quality and interpretations of technical specifications; had different financial and capital structures; & above aII, had diffferent degrees of connection with other related industrial activities, either directly or through their shareholders. The impact of these aspects should be borne in mind in the process of obtaining a perspective of the EEC shipbuilding industry.*
>
> *This is rejected in the different ways the shipyards handle design. Some include it in their overhead and others treat it as a direct cost. An additional problem is what is included in design? Some shipyards include purchasing, material control, planning and production engineering."*

This applies equally well to this project.

The most important myth to be dispelled is that U.S. shipbuilders cannot build ships quickly. Of course they can and have when the situation and environment are appropriate to the need. The primary requirement is a shipbuilding demand (shipyard throughput) sufficiently large to sustain short build cycles. Many people do not seem to understand that there is a direct relationship between shipyard through put and productiviy and build time. Burmeister & Wain have shown this in their plots such as Figure 1 (5). As throughput increases so does productivity and the build time obviously is shortened. Another source has reported that as through put is increased by 10% productivity is increased by 2 l/2%.

However, it makes no sense to shorten design and build times without an increased continuous through put (shipbuilding demand). Even with the increased productivity that will result from the increased through put, it will still be necessary to increase the number of design and production workers and they will need to be trained in the new ways not the traditional ways. This can only be undertaken as a long tern investment. It is ludicrous to man up for one or two short cycle ships and then have to lay off most of the workers because there is no work after that.

A secondary requirement is that the supporting material and equipment suppliers be able to deliver their products in a correspondingly short time. This requires either a well established marine support industry, which the U.S. does not have, or the ability to purchase material and equipment from the world market, which for U.S. ships the shipbuilders have been prohibited from doing by law.

The time to deliver a ship after Contract Award can be divided into it's:

Design
Planning
Fabrication
Assembly
Erection
Afloat Completion
Test and Trials

Sometimes when comparing schedule times it is not clear that the same start stages are used. That is, Contract Award, Start of Design Start of Fabrication or Keel Laying. It is suggested that the best overall measure is Contract Award to Delivery. It can be useful in a more detailed analysis where times to prepare the different phases of the design and build cycle to breakdown the total time into its components, such as erection time. This was done in the study to compare U.S. and Japanese man-hours and schedule for a hypothetical ship prepared by UMTRI (1). Figures 2 and 3 are taken from that paper. Again it is most important to assure that the same activities are being compared.

It is not easy to get a universally accepted definition of productivity. In the shipbuilding industry man-hours/steel weight ton has long been used as a productivity measure but it suffers from the fact that complexity is not taken into account. To overcome this problem man-hours/CGT (Compensated Gross Tonnage) has been accepted as the best measure (8).

	FIRST SHIP			5SHIP AVERAGE			FIFTH SHIP		
	ASI	KHI	RATIO KHI/ASI	ASI	KHI	RATIO KHI/ASI	ASI	KHI	RATIO KHI/ASI
TOTAL PRODUCTION ACTIVITIES, ONLY	1233	588	0.48	1172	556	0.47	1137	535	0.47
DESIGN, PLANNING, AND MOLD LOFT	601	122	0.20	202	38	0.19	98	2	0.02
HULL PRODUCTION ACTIVITIES, ONLY	561	243	0.43	536	229	0.43	523	222	0.42
HULL DESIGN, PLANNING, AND MOLD LOFT	250	68	0.27	106	22	0.21	67	1	0.01
OUTFITTING PRODUCTION ACTIVITIES ONLY	672	345	0.51	636	327	0.51	614	314	0.51
OUTFIT DESIGN, PLANNING, AND MOLD LOFT	351	54	0.15	96	16	0.17	31	1	0.03

~~TABLE 4.3~~ KHI/ASI PRODUCTION COMPARISON FOR THE FIRST, FIFTH, AND AVERAGE OF FIVE SHIPS (IN THOUSANDS MANHOURS)

FIGURE 2

TABLE 4.3 KHI/ASI PRODUCTION COMPARISON FOR THE F , FIFTH, AND AVERAGE OF FIVE SHIPS (IN THOUSANDS MANHOURS)

	-----FIRST SHIP-----			-----5SHIP AVERAGE-----			-----FIFTH SHIP-----		
	ASI	KHI	RATIO KHI/ASI	ASI	KHI	RATIO KHI/ASI	ASI	KHI	RATIO KHI/ASI
HULL ACTIVITIES									
Cut and Fabrication	107	34	0.32	102	32	0.31	99	31	0.31
Sub assy and Assy	135	95	0.70	129	90	0.70	126	86	0.68
Erection	219	96	0.44	209	91	0.44	204	87	0.43
Production Engineering	48	13	0.27	13	5	0.38	4	0	*DIV/0!
Mold Loft	54	32	0.59	52	11	0.21	50	1	0.02
Cranes	56	16	0.29	54	15	0.28	53	15	0.28
Miscellaneous	44	2	0.05	42	2	0.05	41	2	0.05
SubTotal	663	288	0.43	601	246	0.41	577	222	0.38
Design Engineering	148	23	0.16	41	6	0.15	13	0	*DIV/0!
TOTAL HULL ACTIVITIES	811	311	0.38	642	251	0.39	590	223	0.38
OUTFITTING ACTIVITIES									
Piping, Fabrication, and Assembly	125	116	0.93	113	110	0.97	106	106	1.00
Machinery Fab and Assy	49	35	0.71	48	33	0.69	47	32	0.68
Electrical Fab and Assy	60	31	0.52	55	29	0.53	52	28	0.54
Sheet Metal Fab and Assy	64	23	0.36	62	22	0.35	60	21	0.35
Insulation	29	24	0.83	28	23	0.82	27	22	0.81
Painting	107	44	0.41	102	42	0.41	100	40	0.40
Fitting and Outfitting	143	56	0.39	137	53	0.39	134	51	0.38
Testing	32	2	0.06	30	2	0.07	28	2	0.07
Cranes for Outfitting	14	1	0.07	13	1	0.08	13	1	0.08
Services and Unallocated	50	13	0.26	48	12	0.25	47	12	0.26
Outfitting Production Engineering	86	26	0.30	24	9	0.38	8	1	0.13
Subtotal	758	371	0.49	660	336	0.51	622	315	0.51
Design Engineering	265	28	0.11	72	7	0.10	23	0	*DIV/0!
TOTAL OUTFITTING ACTIVITIES	1023	399	0.39	732	343	0.47	645	315	0.49
TOTAL MANHOURS	1834	710	0.39	1374	594	0.43	1235	537	0.43

~~TABLE 4.4~~ KHI/ASI PRODUCTION COMPARISON FOR THE FIRST, FIFTH, AND AVERAGE OF FIVE SHIPS (IN THOUSANDS MANHOURS)

FIGURE 3

Table II gives the "construction time" for the same countries and ship types. It can be seen that the "competitive" design and build cycle time is 18 months for most new commercial ship types other than ferries and passenger ships. Where an existing design is used the Contract Award to Delivery time is reduced to 12 months. This obviously requires a very close relationship between the shipbuilder and the material and equipment suppliers.

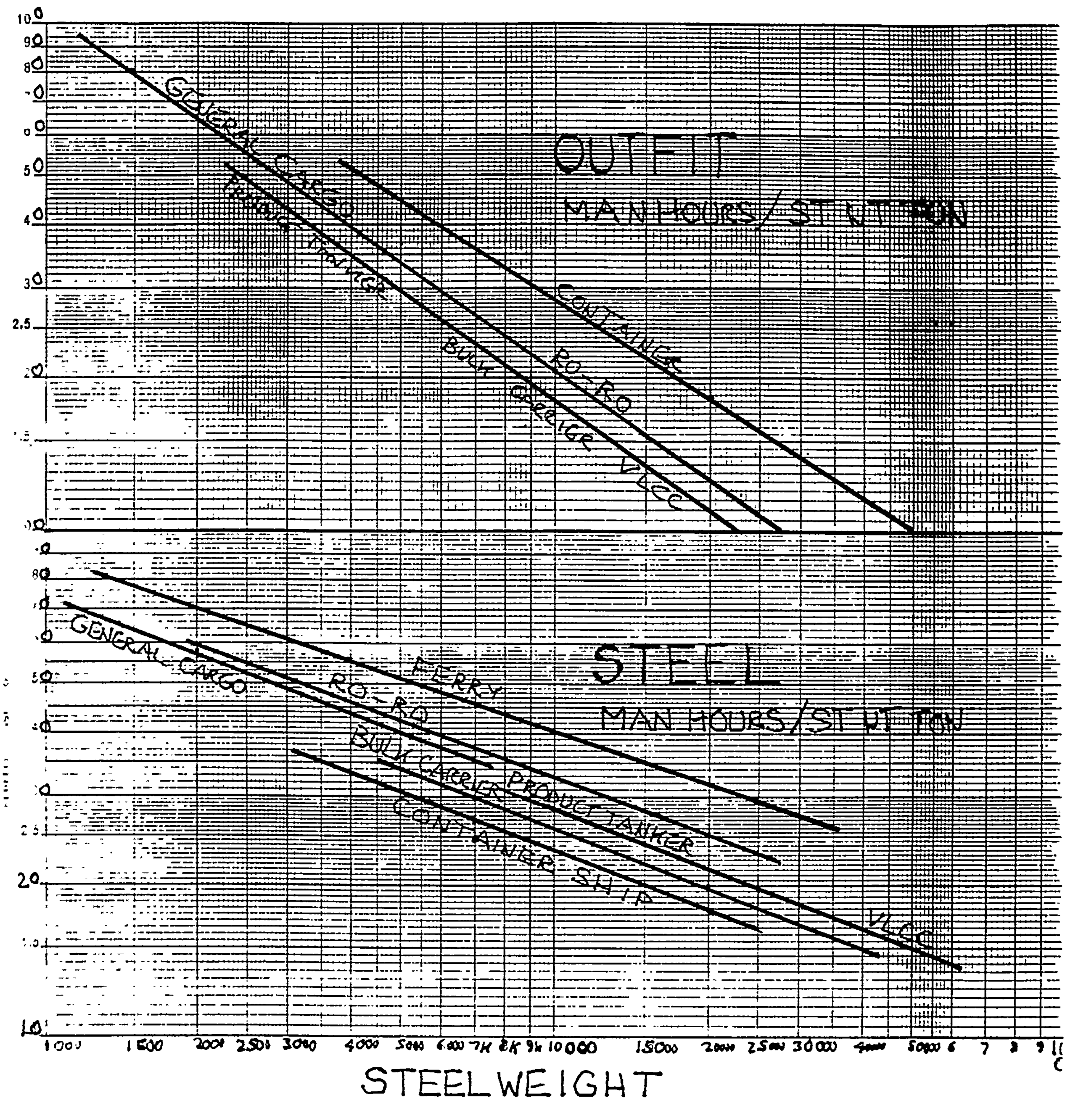
Internationally competitive productivity appears to range from 20 man-hours/CGT for large container ships, to 30 man-hours/CGT for single hull VLCCS, to 40 rnan-hours,/CGT for ferries and 70 man-hours/CGT for passenger ships.

As previously mentioned, Steel Man-hours/Steel Weight Ton is a measure that has been used for years. Even with its limitations, it can still be used for comparison of U.S. productivity with the rest of the world when it is presented for different ship types and sizes. Figure 4 shows plots of this measure as well as Outfit Man-hours/Steel Weight Ton for different commercial ship types and sizes. The data was collected from many sources.

Another area of comparison is the productivity of the design process. Table III shows the design man-hours required for different ship types based on average European performance. This information is taken from (6).

There is a major difference between U.S. and Japanese, and even to a lesser extent European ways of developing shipbuilding technology. In the U.S. the individual shipyards appear to abhor cooperation and prefer to do everything on their own. That this is so is readily supported by the lack of participation of many shipbuilders in the NSRP projects and more recently the way that the MARITEC projects are structured. Instead of a national group taking the lead with all major shipbuilders participating, to develop a single world beating 40,000 TDWT Product Tanker, which would be the Japanese way, we have 20 separate awards given to individual shipyards of which 6 are for 40,000 TDWT Product Tankers and 2 for larger Tankers. bother recent example of the Japanese way is the government sponsored 8 year study into CIM. The Japanese Shipbuilders Association took the lead and the 7 major shipbuilders participated. They anticipated that this research will help them reach their national goal of cutting current man-hours in half by the year 2000. What is the U.S. national goal for shipbuilding shared by both shipbuilders and the government?

Another interesting and important fact reported in (6) is that the world's most successful shipbuilding countries have complete dominance in their domestic ship owner market. Both Japan and Korea build 100% of the ships own by the ship owners in their respective countries. In Europe it is only 60% and this is directly linked to their lack of competitiveness. Also in these countries the industry is very concentrated with 7 Japanese shipbuilders accounting for 92% of all shipbuilding, 4 shipbuilders in Korea with 90% and 2 shipbuilders in Finland with 80%. Again in Europe 3 major shipbuilders account for only 25% of production. In the U.S. there appears to be concentration by the fact that the major shipbuilders are building ships for the navy which is the only large ship owner.



OUTFIT
MAN HOURS/ST WT TON
GENERAL CARGO
PRODUCT TANKER
CONTAINER
RO-RO
BULK CARRIER
VLCC
STEEL
MAN HOURS/ST WT TON
FERRY
GENERAL CARGO
RO-RO
BULK CARRIER
PRODUCT TANKER
CONTAINER SHIP
VLCC
1000
1500
2000
2500
3000
4000
5000
6000
10000
15000
30000
STEELWEIGHT

FIGURE 4

TABLE I
PRODUCTION MANHOURS

SHIP TYPE	CGT	PRODUCTION MANHOURS EUROPE	JAPAN
VLCC	37,500	1,185,000	1,030,000
Product Tanker	21,000	475,000	395,000
Bulk Carrier	31,200	643,000	465,000
Container Ship 4,400 TFEU	35,000	765,000	
Container Ship 1,880 TFEU	19,500	434,000	
Ferry	29,000	1,250,000	

TABLE II
CONSTRUCTION TIME IN MONTHS(Keel Laying to Delivery)

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Container Ship 1,880 TFEU	12	7		24
Ferry	13			

TABLE III
DESIGN MANHOURS

SHIP TYPE	DESIGN MANHOURS (Europe)
VLCC	75,500 Single Hull 102,00 Double Hull
Product Tanker	36,000
Bulk Carrier	48,000
Container Ship 4,400 TFEU	72,500
Container Ship 1,880 TFEU	42,500
Ferry	226,000

GROSS TONNAGE AND COMPENSATED GROSS TONNAGE (CGT) COEFFICIENTS

Gross Tonnage is the base measurement of Admeasurement. Admeasurement has a long history starting with the British in 1066, to measure the number of wine casks, or TUNS, that a commercial ship could carry. Over the years it developed to the stage in 1854 where it basically measured the volume of a ship's hull above the floors and tilde of the hues, added the volume of the superstructure and divided the total volume by 100, the number of cubic feet in a TUN of wine.

Over the years many techniques were developed to minimize the gross tonnage of a ship, such as "deep floors" and "open spaces". International Tonnage Conventions were held to attempt to reduce differences between the various national systems, but they were not too effective as some large shipping countries did not attend. For example the U.S. did not attend a conference in Paris which limited floor height and made water ballest a deduction from the Gross Tonnage to derive the Net Tonnage. The U.S. has no floor height limitation and by an error made water ballast an exemption from the Gross Tonnage. This means that U.S. Gross Tonnages are usually significantly less than that of other countries.

To eliminate national Gross Tonnage differences held a conference in 1970 and approved anew "International Gross Tonnage measurement system. A major aim was to simplify the calculations and eliminate all of the tonnage reduction techniques and differences between countries. Sufficient signatories were received by 1984 and the Tonnage Convention came into force. For a limited time, individual countries can continue to use their own system for domestic flag non-international ships.

The International Gross Tonnage is simply the molded volume, in cubic meters, of the enclosed spaces in the hull and deckhouse of a ship multiplied by a coefficient. The coefficient is to convert volume to admeasurement tons (.35), and to keep the new Gross Tonnage as close to the existing Gross Registered Tonnage as possible. The coefficient ranges from 0.22 for a small boat of 20 cubic meters volume to 0.32 for a very large ship with 1 million cubic meters volume. Most hydrostatic programs used today will give you this volume if the hull and deckhouse are completely defined into the computer model as is normally done for the stabtity calculations.

While most military ships do not have national admeasurement applied, they often have Suez and Panama Admeasurement prepared. These tonnages are based on modtied Moorsom System of admeasurement and have developed many inequities because of different interpretations of international conventions by national governments. However, even though it is very simple to calculate, most military ships do not calculate this new Gross Tonnage (GT).

In order to attempt to develop a productivity measure for U.S. shipyards which could be used to determine competitiveness, Gross Tonnage is required. Estimates of Gross Tomage were made for a number of recent U.S. and British military ships and are given in Table I.

SEE MILITARY GT

PRODUCTIVITY MEASURES

SHIP TYPE	MH/ST. WT. TON	MH/CGT
VLCC	16.0	31.6
SUEZMAX	26.2	30.4
PRODUCT CARRIER	30.9	22.6
CHEMICAL CARRIER	49.8	36.9
BULK CARRIER	19.6	20.6
CONTAINER CARRIER 4,400	18.6	22.0
CONTAINER CARRIER 1,880	26.8	22.3
REEFER	40.7	34.6
FERRY	46.1	43.3
GENERAL CARGO	57.9	16.2
OCEAN TUG	99.5	30.5

cluded from enclosed spaces is limited to the area of the opening (Fig. 9 in Appendix 1).

(e) A recess in the boundary bulkhead of an erection which is exposed to the weather and the opening of which extends from deck to deck without means of closing, provided that the interior width is not greater than the width at the entrance and its extension into the erection is not greater than twice the width of its entrance (Fig. 10 in Appendix 1).

(6) *Passenger*

A passenger is every person other than:

(a) The master and the members of the crew or other persons employed or engaged in any capacity on board a ship on the business of that ship.

(b) A child under one year of age.

(7) *Cargo Spaces*

Cargo spaces to be included in the computation of net tonnage are enclosed spaces appropriated for the transport of cargo which is to be discharged from the ship, provided that such spaces have been included in the computation of gross tonnage. Such cargo spaces shall be certified by permanent marking with the letters CC (cargo compartment) to be so positioned that they are readily visible and not to be less than 100 millimeters (4 inches) in height.

(8) *Weathertight*

Weathertight means that in any sea conditions water will not penetrate into the ship.

Regulation 3
Gross Tonnage

The gross tonnage (GT) of a ship shall be determined by the following formula:

$$GT = K_1 V$$

where

V = Total volume of all enclosed spaces of the ship, cubic metres

K_1 = $0.2 + 0.02 \log_{10} V$ (or as tabulated in Appendix 2).

Regulation 4
Net Tonnage

(1) The net tonnage (NT) of a ship shall be determined by the following formula:

$$NT = K_2 V_2 \left(\frac{4d}{3D}\right)^2 + K_3 \left(N_1 + \frac{N_2}{10}\right)$$

in which formula

(a) The factor $\left(\frac{4d}{3D}\right)^2$ shall not be taken as greater than unity

(b) The term $K_2 V_C \left(\frac{4d}{3D}\right)^2$ shall not be taken as less than 0.25 GT

(c) NT shall not be taken as less than 0.30 GT

and in which

V_C = total volume of cargo spaces, cubic metres

K_2 = $0.2 + 0.02 \log_{10} V_C$ (or as tabulated in Appendix 2)

K_3 = $1.25 \dfrac{GT + 10{,}000}{10{,}000}$

D = moulded depth amidships, metres, as defined in Regulation 2(2)

d = moulded draught amidships, metres, as defined in paragraph (2) of this Regulation

N_1 = number of passengers in cabins with more than 8 berths

N_2 = number of other passengers

$N_1 + N_2$ = total number of passengers the ship is p[…] mitted to carry as indicated in the shi[…] passenger certificate; when $N_1 + N_2$ [is] less than 13, N_1 and N_2 shall be taken [as] zero

GT = gross tonnage of the ship as determined [in] accordance with the provisions of Regu[la]tion 3.

(2) The moulded draught (d) referred to in paragraph (1) of t[his] Regulation shall be one of the following draughts:

(a) For ships to which the International Convention on Lo[ad] Lines in force applies, the draught corresponding to [the] Summer Load Line (other than timber load lin[e]) assigned in accordance with that Convention.

(b) For passenger ships, the draught corresponding to [the] deepest subdivision load line assigned in accordan[ce] with the International Convention for the Safety of L[ife] at Sea in force or other international agreement wh[ere] applicable.

(c) For ships to which the International Convention [on] Load Lines does not apply but which have been assign[ed] a load line in compliance with national requiremen[ts,] the draught corresponding to the summer load line assigned.

(d) For ships to which no load line has been assigned b[ut] the draught of which is restricted in compliance wi[th] national requirements, the maximum permitted draft.

(e) For other ships, 75 percent of the moulded dep[th] amidships as defined in Regulation 2(2).

Regulation 5
Change of Net Tonnage

(1) When the characteristics of a ship, such as V, V_C, d, N_1 [or] N_2 as defined in Regulations 3 and 4, are altered and whe[re] such an alteration results in an increase in its net tonna[ge] as determined in accordance with the provisions of Regul[a]tion 4, the net tonnage of the ship corresponding to the ne[w] characteristics shall be determined and shall be applied wit[h]out delay.

(2) A ship to which load lines referred to in subparagraphs [(1)] (a) and (2) (b) of Regulation 4 are concurrently assigned sh[all] be given only one net tonnage as determined in accordan[ce] with the provisions of Regulation 4 and that tonnage sh[all] be the tonnage applicable to the appropriate assign[ed] load line for the trade in which the ship is engaged.

(3) When the characteristics of a ship such as V, V_C, d, N_1 [or] N_2 as defined in Regulations 3 and 4 are altered or when t[he] appropriate assigned load line referred to in paragraph [(2)] of this Regulation is altered due to the change of the tra[de] in which the ship is engaged, and where such an alterati[on] results in a decrease in its net tonnage as determined [in] accordance with the provisions of Regulation 4, a ne[w] International Tonnage Certificate (1969) incorporating t[he] net tonnage so determined shall not be issued until twel[ve] months have elapsed from the date on which the curre[nt] Certificate was issued; provided that this requirement sh[all] not apply:

(a) If the ship is transferred to the flag of another State.

(b) If the ship undergoes alterations or modifications wh[ich] are deemed by the Administration to be of a ma[jor] character, such as the removal of a superstructure wh[ich] requires an alteration of the assigned load line.

(c) To passenger ships which are employed in the carr[iage] of large numbers of unberthed passengers in spe[cial] trades, such, for example, as the pilgrim trade.

Appendix 2

Coefficients K_1 and K_2 Referred to in Regulations 3 and 4(1)

V or V_c = Volume in cubic metres

V or V_c	K_1 or K_2	V or V_c	K_1 or K_2	V or V_c	K_1 or K_2	V or V_c	K_1 or K_2
10	0.2200	45,000	0.2931	330,000	0.3104	670,000	0.3165
20	0.2260	50,000	0.2940	340,000	0.3106	680,000	0.3166
30	0.2295	55,000	0.2948	350,000	0.3109	690,000	0.3168
40	0.2320	60,000	0.2956	360,000	0.3111	700,000	0.3169
50	0.2340	65,000	0.2963	370,000	0.3114	710,000	0.3170
60	0.2356	70,000	0.2969	380,000	0.3116	720,000	0.3171
70	0.2369	75,000	0.2975	390,000	0.3118	730,000	0.3173
80	0.2381	80,000	0.2981	400,000	0.3120	740,000	0.3174
90	0.2391	85,000	0.2986	410,000	0.3123	750,000	0.3175
100	0.2400	90,000	0.2991	420,000	0.3125	760,000	0.3176
200	0.2460	95,000	0.2996	430,000	0.3127	770,000	0.3177
300	0.2495	100,000	0.3000	440,000	0.3129	780,000	0.3178
400	0.2520	110,000	0.3008	450,000	0.3131	790,000	0.3180
500	0.2540	120,000	0.3016	460,000	0.3133	800,000	0.3181
600	0.2556	130,000	0.3023	470,000	0.3134	810,000	0.3182
700	0.2569	140,000	0.3029	480,000	0.3136	820,000	0.3183
800	0.2581	150,000	0.3035	490,000	0.3138	830,000	0.3184
900	0.2591	160,000	0.3041	500,000	0.3140	840,000	0.3185
1,000	0.2600	170,000	0.3046	510,000	0.3142	850,000	0.3186
2,000	0.2660	180,000	0.3051	520,000	0.3143	860,000	0.3187
3,000	0.2695	190,000	0.3056	530,000	0.3145	870,000	0.3188
4,000	0.2720	200,000	0.3060	540,000	0.3146	880,000	0.3189
5,000	0.2740	210,000	0.3064	550,000	0.3148	890,000	0.3190
6,000	0.2756	220,000	0.3068	560,000	0.3150	900,000	0.3191
7,000	0.2769	230,000	0.3072	570,000	0.3151	910,000	0.3192
8,000	0.2781	240,000	0.3076	580,000	0.3153	920,000	0.3193
9,000	0.2791	250,000	0.3080	590,000	0.3154	930,000	0.3194
10,000	0.2800	260,000	0.3083	600,000	0.3156	940,000	0.3195
15,000	0.2835	270,000	0.3086	610,000	0.3157	950,000	0.3196
20,000	0.2860	280,000	0.3089	620,000	0.3158	960,000	0.3196
25,000	0.2880	290,000	0.3092	630,000	0.3160	970,000	0.3197
30,000	0.2895	300,000	0.3095	640,000	0.3161	980,000	0.3198
35,000	0.2909	310,000	0.3098	650,000	0.3163	990,000	0.3199
40,000	0.2920	320,000	0.3101	660,000	0.3164	1,000,000	0.3200

Coefficients K_1 or K_2 at intermediate values of V or V_c shall be obtained by linear interpolation.

Appendix 3

·eference, Recommendation 2 of the Final as follows:

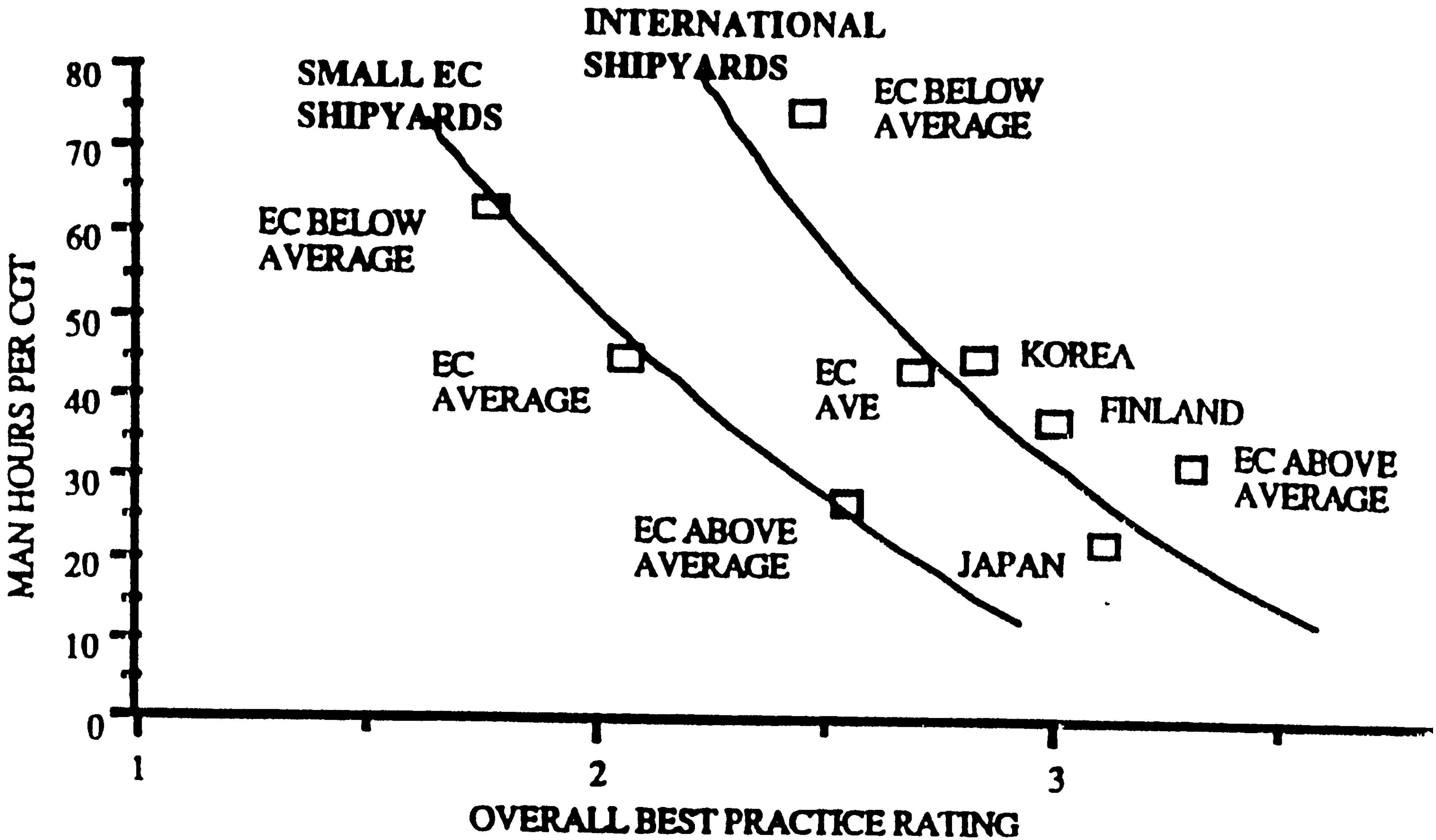
ses of Gross and Net Tonnages

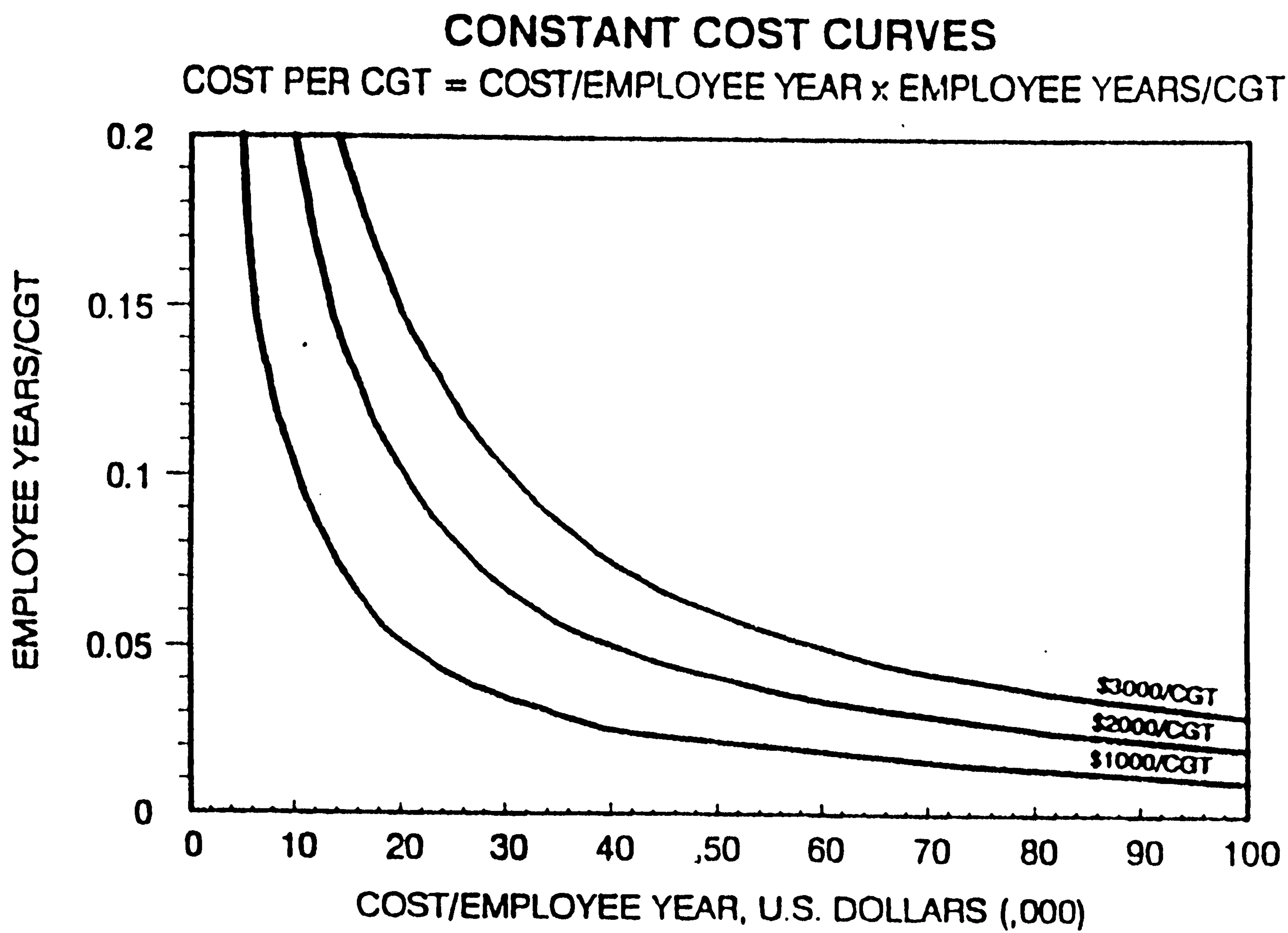
-ence recommends that the gross tonnage onnage as determined in accordance with of the International Convention on Tonments of Ships, 1969, should be accepted ters referred to where those terms are used s, laws and regulations, and also as the basis for statistical data relating to the overall size useful capacity of merchant ships. In addition, recc nizing that the transition from existing tonnage measuı ment systems to the new system provided in the Cc vention should cause the least possible impact on t economics of merchant shipping and port operatioı the Conference recommends that Contracting Goveı ments, port authorities, and all other agencies which ι tonnage as a basis for charges should carefully consic which parameter is most appropriate for their use in t light of their present practice.

Discussion

mon, *Visitor:* I would like to refer partic- ›lution 2. It is true that many ports in the very rough and ready application of the principle. In t first place, with the adoption of the open shelter de

Best Practice/Performance Correlation




CONSTANT COST CURVES
COST PER CGT = COST/EMPLOYEE YEAR x EMPLOYEE YEARS/CGT
EMPLOYEE YEARS/CGT
0.2
0.15
0.1
0.05
0
0
10
20
30
40
,50
60
70
80
90
100
COST/EMPLOYEE YEAR, U.S. DOLLARS (,000)
$3000/CGT
$2000/CGT
$1000/CGT

The next measure that is required to enable productivity comparison is coefficients to apply to the GT to account for the vessel type and size impact on complexity. These have been developed for all types of commercial ships over many years by the OECD and Table II shows the current coefficients. There are no published coefficients for military ships. Therefore, estimates of GT Coefficients were derived from review of suitable (high complexity)commercial ship types and sizes as well as comparison of building manhours for both military and commercial ships. The estimated GT Coefficients for military ships are shown in Table III. These coefficients were derived from a small sample of relatively small (up to 6,000 GT) commercial and military ships from European and a few U.S sources. The ManhoursKiross Tomage values were calculated and plotted on log log scale. The plot showed both the fleet oilers and the LSD on a much lower curve than the combatant ships. The ratio of the measure for militay compared to commercial ships was determined and applied to the current CGT Coefficients for Ferries and Passenger at different Gross Tonnage. The military combatant line was projected as a straight line to the size of the LID and Aircraft Carrier.

TABLE III
ESTIMATED CGT COEFFICIENTS FOR MILITARY `SHIPS

Frigates	10 to 18
Destroyers	8 to 14
Cruisers	7 to 12
Aircraft Carrier	2 to 4
LSD	2 to 4
LID	3 to 5
Fleet Oiler	1.5 to 2

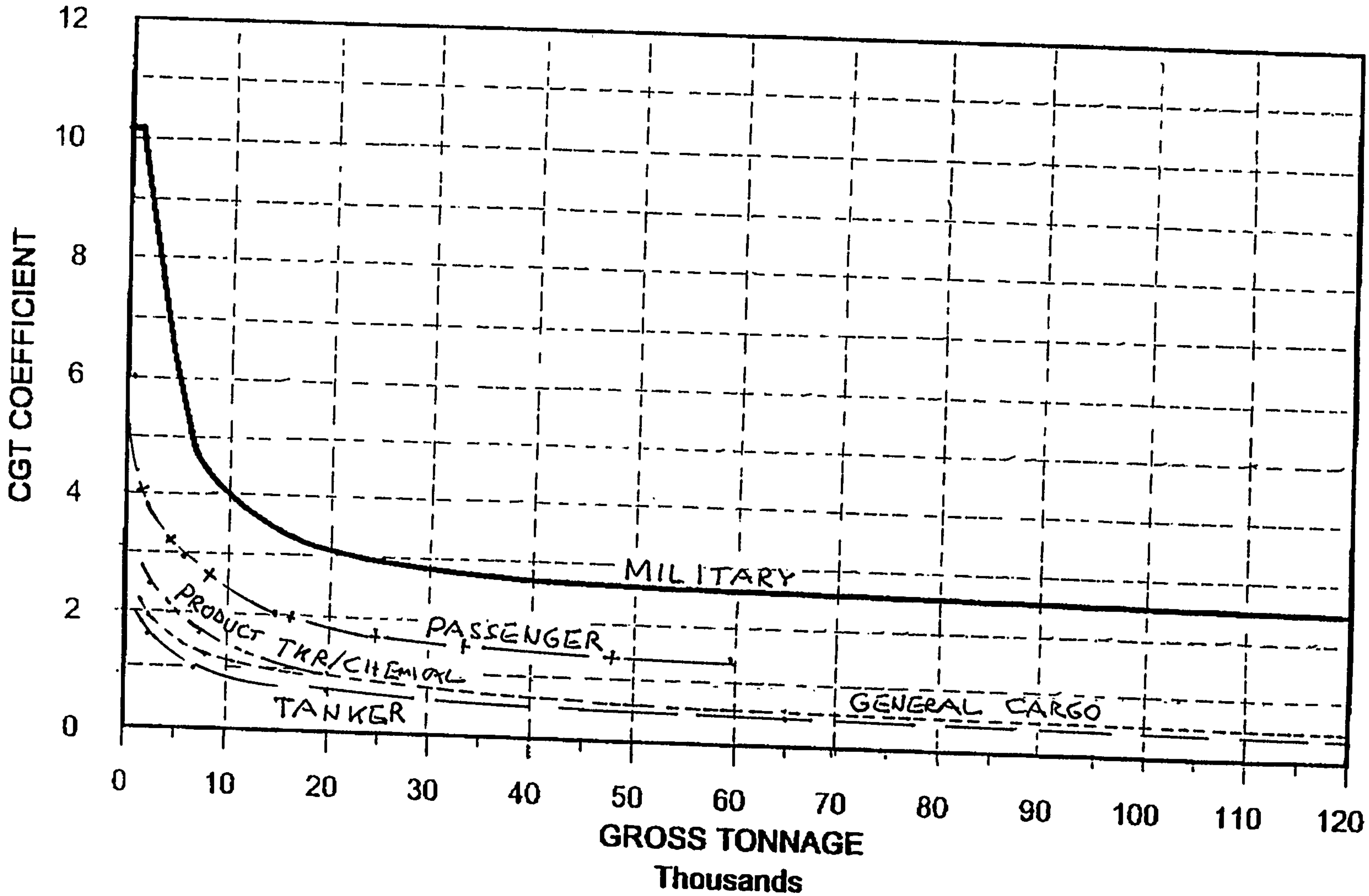
Applying these coefficients to the fist of a class of a military support ship, built in a U.S. shipyard in 1984, gives a productivity factor ranging from 74 to 148 MWCGT. These values are well above European and Japanese shipbuilding productivity for complex ships of similar size which would be in the low 40's.

It is recommended that individual U.S. shipyards start to use this approach to measure productivity for every ship they are currently building and for all fiture bids and building. They can start by using the estimated CGT Coefficients in Table III with their calculated Gross Tonnage to determine the productivity factor. This would enable them to refine the coefficients over time and by comparing different ship types in the same shipyard. For example Ingalls Shipbuilding could compare Aegis Cruisers, DDG 51 Destroyers, LHA's and LHD's. It would be reasonable to expect lower manhours per CGT values for the larger ships. The results could also be used to record impact of design changes and improved processes.

It is suggested that at a minimum the following measures be derived:

Direct Manhours/CGT
Total Employee Manhours/CGT
CGT/Direct worker Year
CGT/Total Employee Year

CGT COEFFICIENTS FOR NAVAL SHIPS



MILITARY GROSS TONNAGE AND COMPENSATED GROSS TONNAGE (CGT) COEFFICIENTS

While most military ships do not have national admeasurement applied, they often have Suez and Panama Admeasurement prepared. These tonnages are based on modified Moorsom System of admeasurement and have developed many inequities because of different interpretations of international conventions by national governments. Because of this, IMO held a convention in 1970 that agreed on a simplified approach to be applied internationally, and this system came into force in 1984. However, even though it is very simple to calculate, most military ships do not calculate this new Gross Tonnage (GT).

The International Gross Tomage is simply the volume, in cubic meters, of the enclosed spaces in the hull and deckhouse of a ship multiplied by a coefficient. The coefficient is to convert volume to admeasurement tons (.35), and to keep the new Gross Tonnage as close to the existing Gross Registered Tonnage as possible. The coefficient ranges from .22 for a small boat of20 cubic meters volume to .32 for a very large ship with 1 million cubic meters volume. Most hydrostatic programs used today will give you this volume if the hull and deckhouse are completely defined into the computer model as is normally done for the stabtity calculations.

The team was unable to obtain this information from the U.S. military ships from the shipyards visited. They did receive the Gross Tomages for the Avondale built Fleet Oilers but it is uncertain if they were U.S. or International Gross Tonnages. Although from the low value compared to the estimated value it is believed that they were the old U.S. Gross Registered Tonnage which allows exemption of water ballast spaces and does not include the volume in double bottom.

In order to attempt to develop a productivity measure for U.S. shipyards which could be used to determine competitiveness, Gross Tomage is required. Estimates of Gross Tonnage were made for a number of recent U.S. and British military ships and are given in Table I.

TABLE I
ESTIMATED GROSS TONNAGE FOR MILITARY SHIPS

FRIGATES	**GROSS TONNAGE**	
British Type 22	**4,950**	
British Type 23	**3,800**	
USA FFG	**4,725**	
DESTROYERS		
British Type 82	**6,000**	
USA DDG 51	**8,750**	
OTHER		
USA AEGIS	**8,050**	
USA LSD	**17,700**	
USA LHD	**74,200**	
USA Aircraft Carriers	**108,000**	
USA Fleet Oiler	**25,500**	**Avondale**
USA Fleet Oiler	**38,500**	**NASSCO**

Ship Type/Type de Navire	CGRT Coefficient 1977 (IUBC)	CGT Coefficient 1984 (IUC)
B: MISCELLANEOUS VESSELS/NAVIRES DIVERS (cont)		
Fishing Vessels/Navires de Peche		
100-1,000 gt		4.00
1,000-3,000 gt		3.00
3,000 gt and over		2.00
Others (including tugs dredgers, etc)/Augres (y compris trorquers, drauges, etc)		
100- 1,000 gt		5.00
1,000- 3,000 gt		3.20
3,000-10,000 gt		2.00
10,000 gt and over		1.50

1. Apply same coefficients as "Bulk Carriers"/Appliquer les sames coefficients que "Navires Vracquiers".

2. Apply same coefficients as "Combined Carriers"/Appliquer les sames coefficients que "Transporteurs Combines".

3. Apply same coefficients as "General Cargo"/Appliquer les sames coefficients que "Cargos".

4. In the 1977 system "Chemical carriers" were included in "LPG Carriers"/Dan le systeme de 1977 les "Transporteurs de Produits Chimiques" entant inclus dans "Transporteurs GPL".

5. Apply same coefficients as "LPG Carriers"/Appliquer les sames coefficients que "Transporteurs GPL".

6. CGRT coefficients in force since 1.1 1983/Coefficients CGRT appliques depuis 1.1 1983.

7. In the 1977 system the heading was "Full Container Ships/High Speed Liners"/Dans le systeme de 1977 le titre etait "Navires Containeurs et de lingne rapides".

8. In the 1977 system the heading was "Ro-Ro Vessels/Car Carriers"/Dans le systeme de 1977 le titre etait "Navires Roulers et Transporteurs d'automobiles".

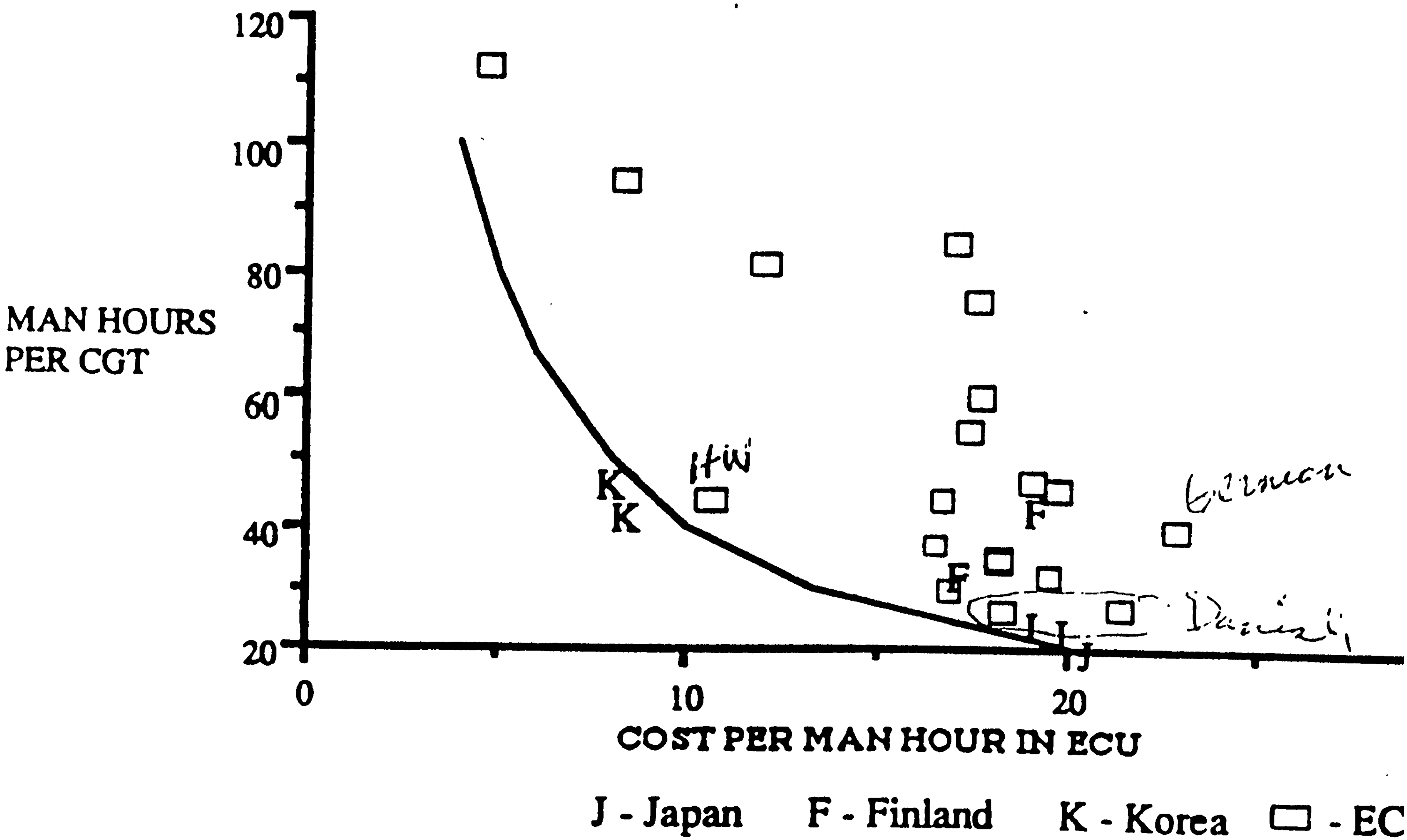
( ) The subdivision did not exist in the 1977 system/Le sous division n'existait pas dan le system de 1977.

Ship Type/Type de Navire	CGRT Coefficient 1977 (TUBC)	CGT Coefficient 1984 (IUC)	
A: CARGO SHIPS/CARGOS (cont)			
Full Container Ships (7)/Navires Containmeurs (7)			
Under 4,000 dwt	3.00	1.85	(3)
4- 10,000 dwt	1.40	1.20	
10- 20,000 dwt	(0.90)	0.90	
20- 30,000 dwt	(0.90)	0.80	
30- 50,000 dwt	(0.80)	0.75	
50,000 dwt and over	(0.80)	0.65	
Ro-Ro Vessels (8)/Navires Rouliers (8)			
Under 4,000 dwt	3.00	1.50	
4- 10,000 dwt	2.00	1.05	
10- 20,000 dwt	(1.60)	0.80	
20- 30,000 dwt	(1.60)	0.70	
30,000 dwt and over	(1.60)	0.65	
Car Carriers (8)/Transporteurs de Voitures (8)			
Under 4,000 dwt	3.00	1.10	
4- 10,000 dwt	2.00	0.75	
10- 20,000 dwt	(1.60)	0.65	
20- 30,000 dwt	(1.60)	0.55	
30,000 dwt and over	(1.60)	0.45	
LPG (4)/Transporteurs de Gaz de Petrols Liquids (4)			
Under 4,000 dwt	2.50	2.05	
4- 10,000 dwt	1.60	1.60	
10- 20,000 dwt	(1.00)	1.15	
20- 30,000 dwt	(1.00)	0.90	
30- 50,000 dwt	(0.80)	0.80	
50,000 dwt and over	(0.80)	0.70	
LNG Carriers/Transporteurs de Gas Natural Liquids			
Under 4,000 dwt	2.50)	2.05)	
4- 10,000 dwt	1.60)	1.60)	(5)
10- 30,000 dwt	(0.90)	1.15)	
		0.90)	
30- 50,000 dwt	0.70	0.80)	
50,000 dwt and over	0.50	0.60	
B: MISCELLANEOUS VESSELS/NAVIRES DIVERS			
Ferries (6)/Transporteurs de Voitures (6)			
100- 1,000 gt	(2.50)	3.00	
1,000- 3,000 gt	(2.50)	2.25	
3,000-10,000 gt	(2.50)	1.65	
10,000-20,000 gt	(1.50)	1.15	
20,000 gt and over	(1.30)	0.90	
Passenger Ships (6)/Paquebots (6)			
100- 1,000 gt	(1.50)	6.00	
1,000- 3,000 gt	(1.50)	4.00	
3,000-10,000 gt	(1.50)	3.00	
10,000-20,000 gt	(1.50)	2.00	
20,000 gt and over	(1.50)	1.50	
Other Non-Cargo Vessels/Autres-Navires Non Cargos			
Under 100 grt	5.00		
100 - 2,000 grt	3.00		
2,000 grt and over	2.00		

COMPENSATED GROSS TONNAGE COEFFICIENTS

Ship Type/Type de Navire	CGRT Coefficient 1977 (TU8C)	CGT Coefficient 1984 (TUC)	
A: CARGO SHIPS/CARGOS			
Crude Oil Tankers/Petroliers			
Under 4,000 dwt	2.50	1.70	
4- 10,000 dwt	1.80	1.15	
10- 30,000 dwt	0.65	0.75	
30- 50,000 dwt	0.50	0.60	
50- 80,000 dwt	0.45	0.50	
80-160,000 dwt	0.40	0.40	
160-250,000 dwt	0.35	0.30	
250,000 dwt and over	0.30	0.25	
Product & Chemical Carriers (4)/Transporteurs de Produits Petroliers et Chimiques			
Under 4,000 dwt	2.50	2.30	
4- 10,000 dwt	1.80	1.60	
10- 30,000 dwt	0.80	1.00	
30- 50,000 dwt	0.60	0.75	
50- 80,000 dwt	(0.50)	0.55	
80,000 dwt and over	(0.50)	0.50	
Bulk Carriers ex Combined Carriers/ Transporteure de Vrac (Transporteurs Combines Exclus)			
Under 4,000 dwt	2.50	1.60	
4- 10,000 dwt	1.80	1.10	
10- 30,000 dwt	0.60	0.70	
30- 50,000 dwt	0.50	0.60	
50- 80,000 dwt	(0.45)	0.50	
80-160,000 dwt	(0.40)	0.40	
160,000 dwt and over	(0.40)	0.30	
Combined Carriers/Transporteurs Combines			
Under 4,000 dwt	2.50)	1.60)	(1)
4- 10,000 dwt	1.80)	1.10)	
10- 30,000 dwt	0.65	0.85	
30- 50,000 dwt	0.55	0.70	
50- 80,000 dwt	(0.50)	0.55	
80-160,000 dwt	(0.45)	0.45	
160,000 dwt and over	(0.45)	0.35	
General Cargo Ships/Cargos			
Under 4,000 dwt	3.00	1.85	
4- 10,000 dwt	1.40	1.35	
10- 20,000 dwt	(1.00)	1.00	
20- 30,000 dwt	(1.00)	0.85	
30- 50,000 dwt	(1.00))	0.70)	
50- 80,000 dwt	(1.00))	0.55)	(2)
80-160,000 dwt	(1.00))	0.45)	
160,000 dwt and over	(1.00))	0.35)	
Reefers/Navires Refrigeres			
Under 4,000 dwt	3.00	2.05	
4- 10,000 dwt	2.00	1.50	
10,000 dwt and over	1.40	1.25	

Shipyard labour cost comparisons



national shipbuilders. An assessment therefore has to be made on the size of the "open" market.

Table II - Ship Type Relative Market Share

SHIP TYPE	RELATIVE MARKET VOLUME
Bulk Carrier	62.3
General Cargo	[illegible]3.5
Tanker	31.5
Container ship	21.6
Passenger (incl. Ferries)	17.4
Chemical Tanker	17.1
RO-RO	13.9
Reefer	12.8
LPG	5.0
OBO	1.3
LNG	1.0

Note - The Relative Market Volume is derived by assigning a value of one to LNG ships

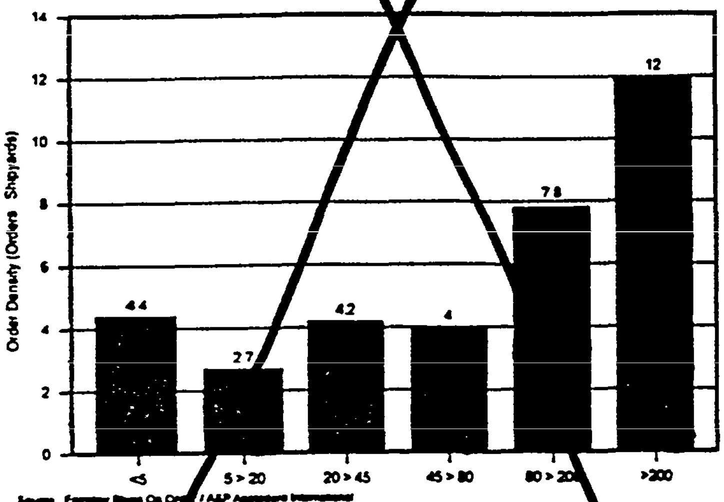


Figure 3 - Order Density in Tanker Market

No matter what strategy is followed, any shipbuilder entering the world commercial shipbuilding market over the next few years, can expect intense competition and probably low profits, if any.

U.S. SHIPBUILDING SITUATION

Competitiveness

Success in the world market requires more than high productivity. Marketing specialists define competitiveness as product, price, place and promotion. However, there is no universally accepted definition of competitiveness. KPMG Peat Marwick, in their study of the Competitiveness of EEC Shipyards (KPMG, 1992), define it as:

"The ability to win and execute shipbuilding orders in open competition and stay in business."

A more measurable definition is that competitiveness is the combined result of price, delivery, quality (customer satisfaction) and financing.

Price is whatever the open market will bear for your product. It is obviously influenced by the balance between demand and supply. Cost, which hopefully will be lower than price giving a profit, depends on material cost, labor rate and productivity

It is difficult to compare U.S. shipbuilding competitiveness as there has been no international trade commercial shipbuilding in the U.S. for so many years, thus the comparative data is non-existent.

Success also depends on other factors such as:

- design of products that are most appropriate for their intended use and are reliable in both function and performance,
- carefully targeted, accessible markets,
- attractive financing packages, and
- product guarantees and in service support.

As U.S. shipbuilders focus on commercial ships the need for total implementation of world class commercial shipbuilding best practices becomes painfully clear. They have to reduce the cost and shorten the design and building time for commercial ships. The dilemma facing them is how to do this in a dual purpose facility? This will be discussed further later.

Cost

Compensated Gross Tons (CGT) is used to provide a common measure of the output of commercial shipbuilding, in large aggregates such as countries, or regions of the world. The associated coefficients are in the form of stepped functions but with some modifications to remove the steps, CGT can be applied to individual shipyards.

The cost in U.S. dollars of producing a CGT can be used to provide a measure of the competitiveness of shipyards. This measure only relates to the labor cost of producing a CGT and thus relates to the portion of the total cost of a ship which is directly under the control of the shipyard.

The supply chain and associated material cost are an important part of the total ship costs and these need to be addressed.

The 1994 Global Shipbuilding Competitiveness study assessed the competitiveness of the U.S. shipbuilding industry in terms of the cost of producing a CGT compared with the same measure for its competitors. The competitors were the three foreign shipyards involved in the survey as well as other world shipyards considered to be competitors for which

comparable data was available. Table III shows the results of this comparison.

Table III - Average Competitiveness Comparison

	U.S. Yards	Visited Foreign	All Foreign
Man Hours/Year	1,829	1,805	1,963
Man Hours/CGT	185	40	88
Cost/Employee Year	$52,500	$63,455	$48,690
Cost/CGT	$5,314	$1,121	$1,296

It is acknowledged that the value for U.S. yards is based on an estimated CGT coefficient, but, it would need to be out by a factor of four to bring U.S. shipyard productivity into line with the foreign shipyards and this is unlikely.

Figure 4 shows the relative competitiveness of various shipbuilding countries in terms of Cost/CGT in U.S. dollars, plotted against a background of curves of constant cost per CGT. The values do not include material costs but are a measure of those items under the direct control of the shipyard.

Total cost to be considered for international competition is given by:

Exchange Rate X {(Fully Burdened Labor Rate X Labor Hours)+ Material Cost}

Thus competitiveness is directly influenced by:

- Productivity
- Delivery Schedule — Shipyard
- Material Cost — Influenced
- Labor Rates
- Financing
- Exchange Rates — Country
- National Shipbuilding Policy — Influenced
- Marine industry Infrastructure
- Subsidies

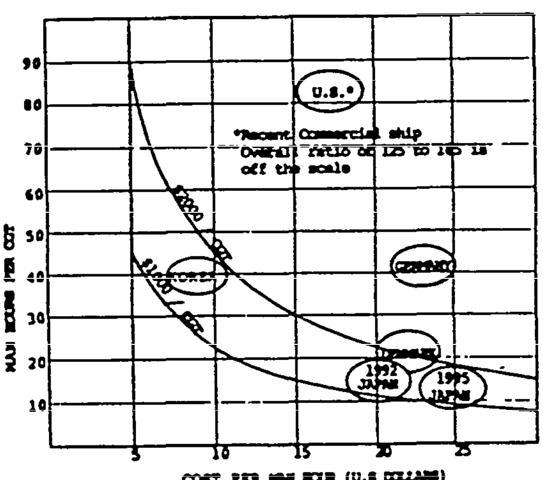


Figure 4 - Shipbuilding Competitiveness

Exchange rate is not within the direct control of a shipbuilder and fluctuates all the time. Even the labor rate is only within a little of the shipbuilders control. Therefore, many analysts prefer to consider labor man hours as a relatively stable measure for comparison. This leads to the consideration of productivity.

It can be seen that Productivity is only one of many factors that influence competitiveness. But it is an important part as it can be controlled by the shipbuilder. Productivity, in turn, is influenced by the following factors:

- Technology
- Facilities
- Management Competence
- Work Organization
- Work Practice
- Worker Skill Level
- Worker Motivation

The Global Shipbuilding Competitiveness studies, mentioned above (NSRP, 1995), included a comparison between the previous and latest studies of technology levels. Table IV is such a comparison and it shows that in 16 years the average technology level in U.S. shipyards has increased by 0.9, from 2.5 to 3.4, but the corresponding increase for foreign shipyards was 1.1, from 2.9 to 4.0. That is, the technology gap has widened slightly. The maximum attainable technology level in 1978 was 4.0 while the current maximum level is 5.0. This is due to the technology developments in the time from 1978 to the present.

It is equally difficult to get a universally accepted definition of productivity. In the shipbuilding industry, man hours per tonne of steel weight has long been used as a productivity measure, but it suffers from the fact that ship type, size and complexity are not taken into account and that outfitting is not addressed. To overcome this problem the concept of Compensated Gross Ton (CGT) was developed in 1967 by the Association of West European Shipbuilders and the Shipbuilders Association of Japan.

The CGT measure uses coefficients to apply to the Gross Tonnage of ships to account for their type, size and complexity. These coefficients have been developed over many years through negotiation between major shipbuilding countries. They cover all commercial ship types.

Man hours per CGT has been accepted as a measure of productivity. A comparative productivity measure used for assessing an individual shipyard's performance is it's labor hours for producing a CGT over a period of 3 to 5 years.

How effective is the CGT approach? If it was precise, for different ship types, sizes and complexity constructed in the same shipyard, the man hours per CGT would be the same. Table V shows a comparison

Table IV - 1978 Survey Results Compared to 1994 Survey Results

GROUP	1978 SURVEY U.S. SHIPYARDS	1978 SURVEY FOREIGN SHIPYARDS	1978 SURVEY DELTA	1994 SURVEY U.S. SHIPYARDS	1994 SURVEY FOREIGN SHIPYARDS	1994 SURVEY DELTA
A Steelwork Production	2.25	2.91	0.66	2.91	3.46	0.55
B Outfit Production and Stores	2.36	2.43	0.07	3.30	3.75	0.45
C Other Pre-Erection Activities	2.06	2.76	0.70	3.83	4.06	0.23
D Ship Construction	2.48	2.86	0.38	3.18	3.98	0.80
E Layout and Environment	2.33	2.89	0.56	2.94	3.31	0.37
G Design/Drafting/ Production Eng/Loft	2.92	3.17	0.25	3.45	4.33	0.88
H Organization and Operating Systems	2.98	3.03	0.05	4.04	4.67	0.63
OVERALL TECHNOLOGY LEVEL	2.5	2.9	0.4	3.4	4.0	0.6

between man hours/tonne of steel and man hours/CGT. It can be seen that there is significant improvement in the CGT approach but it still is not precise.

The best international productivity appears to range from 20 MH/CGT for large container ships, 30 MH/CGT for single hull VLCCs, 40 MH/CGT for large ferries and 70 MH/CGT for passenger ships.

CGT coefficients are not available for naval ships. In order to attempt to derive a rough order of magnitude productivity measure for U.S. shipbuilders in the recent Global Shipbuilding Competitiveness study performed for the NSRP SP-4 Panel (NSRP, 1995), CGT coefficients were estimated for naval ships. These were then applied to data from a number of U.S. shipyards for

Table V - Comparison of Productivity Measures

SHIP TYPE	MH/ST. WT. TONNE	MH/CGT
VLCC	16	32
SuezMax Tanker	19	22
Product Tanker	27	20
Chemical Tanker	46	36
Bulk Carrier	19	20
Container ship 4400TFEU	19	22
Container ship 1800TFEU	28	22
Reefer	43	34
General Cargo	56	29
Ferry	51	39
Ocean Tug	105	31

naval ships, and the resulting productivity ranged 180 MH/CGT for a destroyer to 120 MH/CGT for a l amphibious ship. These values are significantly v than European and Japanese shipbuilding produc values for complex ships.

The Global Shipbuilding Competitiveness : also developed an overall measure of U.S. shipbui productivity by deriving the total output over the pas years of the shipyards visited, in terms of CGT an man hours to produce it. These were 1,683,671 CGT 314,274,641 man hours. The average productivity therefore 185 man hours/CGT. This is higher tha values given above for the destroyer and the amphibi ship, but probably presents a worse case than act exists, due to the fact that some of the shipyards "planning yard" and other "white collar" Navy su activities that expend man hours without prod additional output.

Build Cycle Time

Ship build cycle times for U.S. shipbuilders a to be twice as long as those attained by world shipbuilders.

How is it the U.S. cannot match this? The W War II records show that fast ship production achieved by the U.S. So the U.S. has built ships qui What is different today? It is the lack of steady de for new ships. Many people do not seem to under that there is a direct relationship between shi throughput and productivity and build time. This

shown many years ago by Burmeister & Wain (Sverdrup, 1978). As throughput increases so does productivity and the build time is obviously shortened. Another source has reported that as throughput is increased by 10%, productivity increases by 2 1/2%.

However, it makes no sense to shorten design and build times without an increased continuous demand for ships. Even with the improved productivity that will result from the increased throughput, it will still be necessary to increase the number of design and production workers and they will need to be trained in the new ways, not the traditional ways, to design and build ships. This can only be done as a long term investment. It would be ludicrous to man-up for one or two short cycle ship programs and then have to lay off most of the workers because there was no follow on contracts.

The time to deliver a ship after Contract Award can be divided into:

- Design and Planning
- Fabrication
- Assembly
- Erection
- Afloat Completion
- Test and Trials

Sometimes when comparing build cycle times it is not clear that the same start stages are used. That is, is the start Contract Award, Start of Design, Start of Fabrication or Keel laying? It is essential that the same activities are being compared. Two cycle times are important from the competitiveness point of view, namely design and construction. Typical design time for commercial ships in Europe and Japan range from 6 to 12 months, whereas in the U.S. it ranges from 12 to 24 months. Part of the reason for this is that in the U.S. it takes twice the effort as shown in Table VI (A. Anderson, 1993).

Table VI - Typical Design Man Hours

SHIP TYPE	EUROPE/JAPAN	U.S.
VLCC	75,000 Single Hull 102,000 Double Hull	
Product Tanker	34,000	98,000
Bulk Carrier	56,000	
Container ship 4400	72,500	
Container ship 1800	40,000	110,000

Table VII shows typical construction times for different ship types and countries. The data for the U.S. is sparse but it does highlight the problem.

Table VII - Construction Time in Months
Keel Laying to Delivery

SHIP TYPE	EUROPE	DENMARK	JAPAN	U.S.
VLCC	17	5	9	
Product Tanker	12		8	20
Bulk Carrier	16		8	
Container ship 4400	17	8	9	
Container ship 1880	12	12		24

TECHNOLOGY TRANSFER

In the manufacturing industries, it is generally the Japanese companies that have led the world in terms of cost effective production of well designed, reliable, high quality products.

The Japanese approach to low cost manufacturing can be summarized as:

1. Designing out of the product needless work of construction.
2. Organizing out of production system needless work of construction.
3. Avoiding the need for rework.

This is allied to a consistent policy of continuous improvement.

Just how all of this is achieved is the very essence of a Japanese company's method of operation, that evolves over time in a purposeful, dynamic, well managed manner. For the leading Japanese shipbuilders, this evolution has been underway over the last 40 to 45 years.

The industrial and commercial performance of Japanese manufacturing have set the benchmarks by which others can measure and compare their own performance. To compete with them in world markets, it is at least necessary to match the combined effect of product features valued by customers, including price, quality and delivery. Nowhere is this more true than in shipbuilding.

In many countries the manufacturing companies aim to be competitive in both the domestic and international markets. To do so it is necessary that they become what is generally referred to as "world class in manufacturing practice." This essentially consists of finding out how comparable competitors, usually, but not exclusively, Japanese companies, have achieved their performance, then emulating it by using either the same methods or others that are demonstrably at least equally effective or better.

To date various means of effecting this emulation have been attempted, such as:

- technology transfer,
- partnership with a recognized leader, or
- inward investment by a recognized leader.

WHAT DO U.S. SHIPYARDS NEED TO DO TO BECOME INTERNATIONALLY COMPETITIVE?

So how can the U.S. shipbuilders become internationally competitive? The following suggestions are only the beginning but are important first steps:

1. Quickly learn how to cooperate and undertake joint ventures with other shipbuilders to develop the necessary significant and expensive technology research. Even the largest U.S. shipbuilder working alone will not achieve the national goal of capturing a reasonable share of the world shipbuilding market.

2. Shipbuilders must first concentrate on the many U.S. ship owners that build all their ships abroad. Without a significant change in this area it will be very diflicuk to achieve the demand level necessary for the U.S. shipbuilders to attain short cycle times. This in turn will prevent them from achieving world shipbuilding competitiveness.

3. Shipbuilders should form strategic alliances with ship owners, charterers, suppliers, financial and trading houses in a similar way to the Japanese and even the Germans.

4. Marketing must become proactive instead of reactive. Successful foreign shipbuilders spend up to 2.5% of their sales on marketing.

5. Shipyards should focus on specific ship types and sizes and not try to be flexible enough to build any ship type. The drive for flexibility in ship type is the small to medium European shipyards is believed to be the reason for their poor performance and lack of success. European shipbuilders that focus on specific ship types such as Meyer Vaerft in Germany, Odense Steel Shipyard in Denmark and the Finish passenger ship shipbuilders have done relatively well.

6. Perhaps the most difficult step of all will be to establish separate military and commercial divisions and tier some success even separate shipyards. Shipbuilders throughout the world have shown that dual purpose shipyards cannot be internationally competitive. Even in Japan dual purpose shipyards have productivity problems. U.S. dual purpose aircraft manufacturers learned this lesson along time ago.

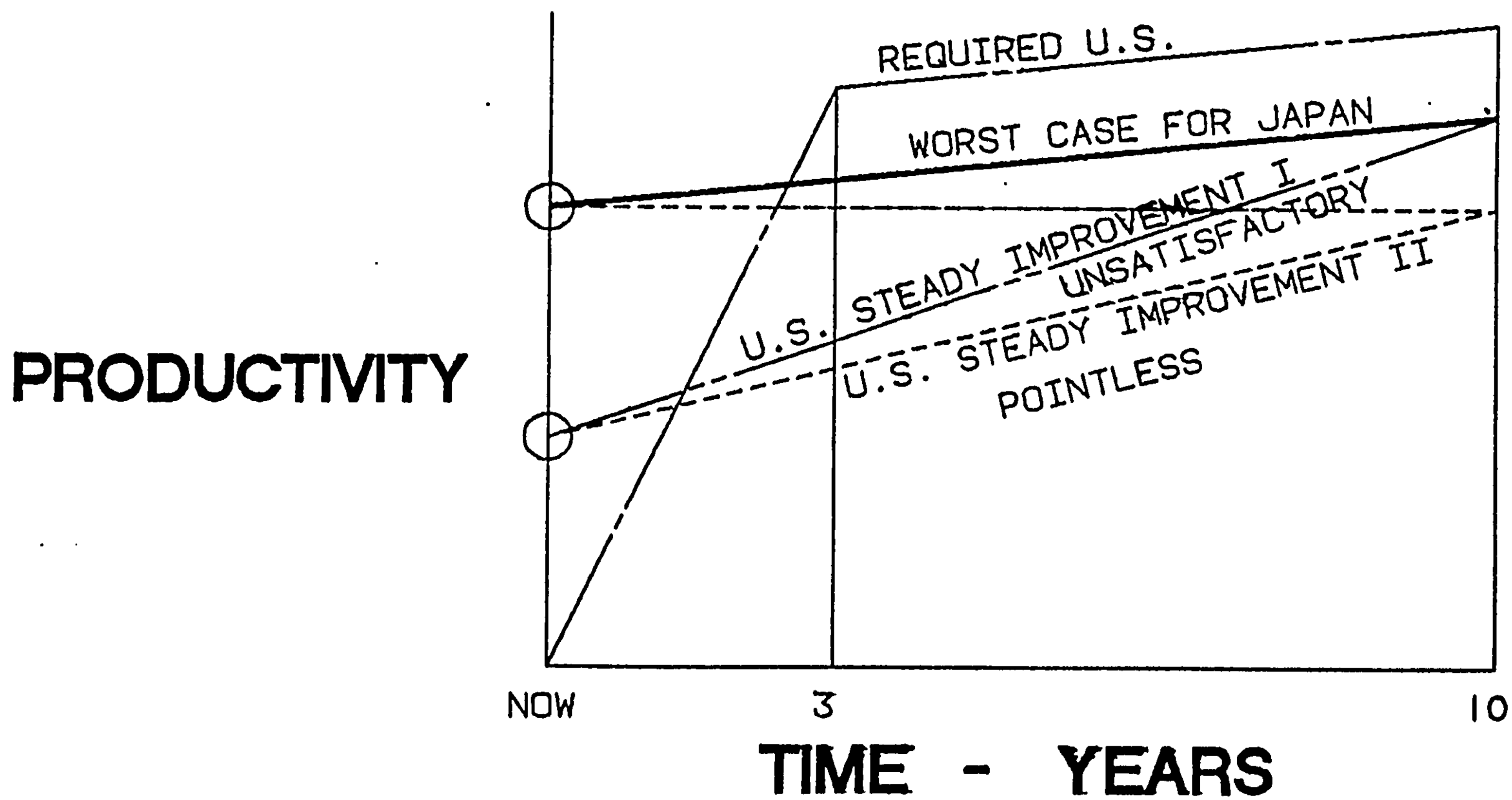


FIGURE 5.14 - U.S. REQUIRED PRODUCTIVITY IMPROVEMENT

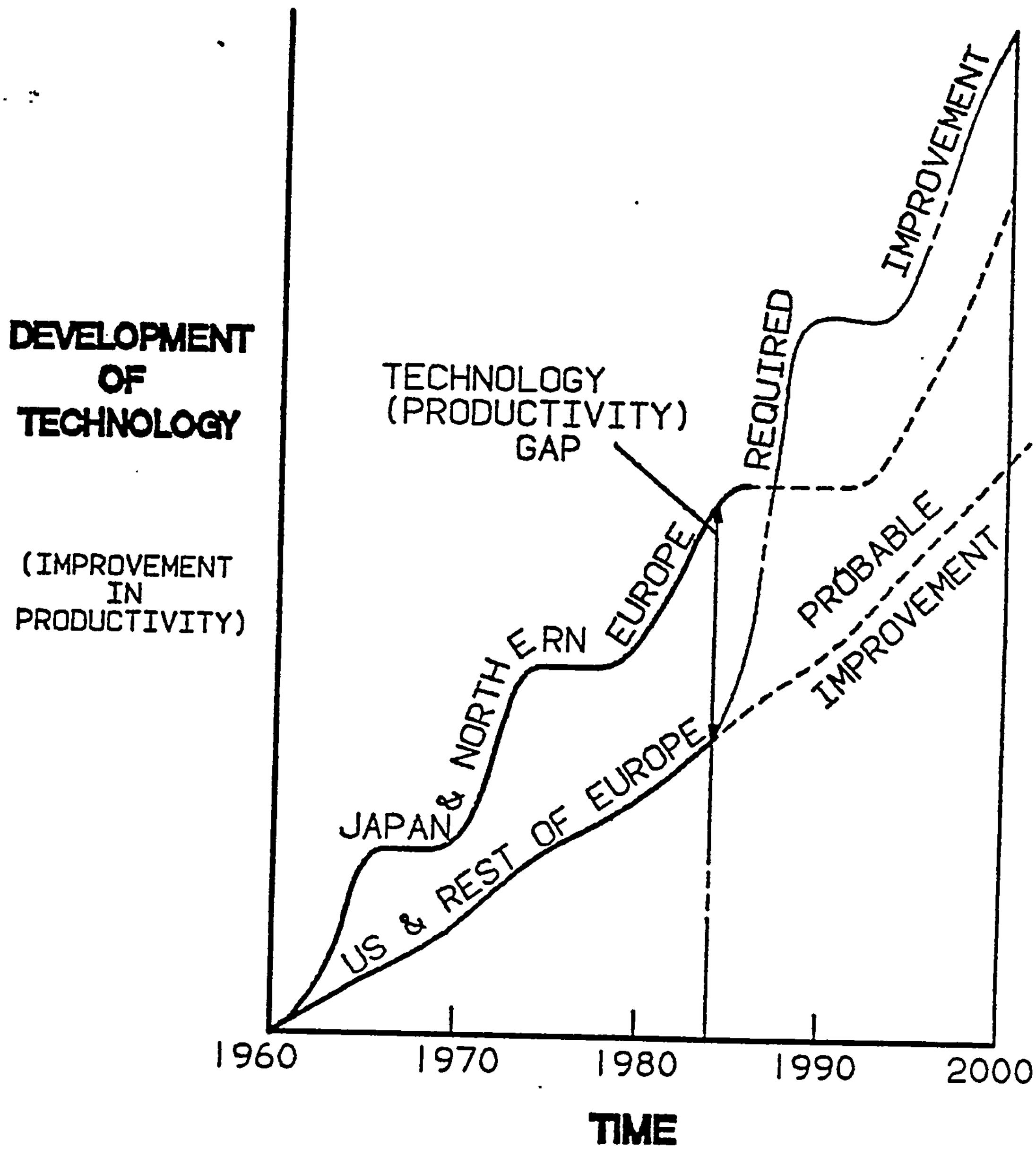


FIGURE 5.16 - TECHNOLOGY (PRODUCTIVITY) REQUIREMENTS

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NEED FOR CHANGE

THE PLAYING FIELD

30 **MILLION GT WORLD SHIPBUILDING CAPACITY**

CURRENTLY 20 MILLION GT WORLD SHIPBUILDING DEMAND

DEMAND IS INCREASING, BUT SO IS CAPACITY

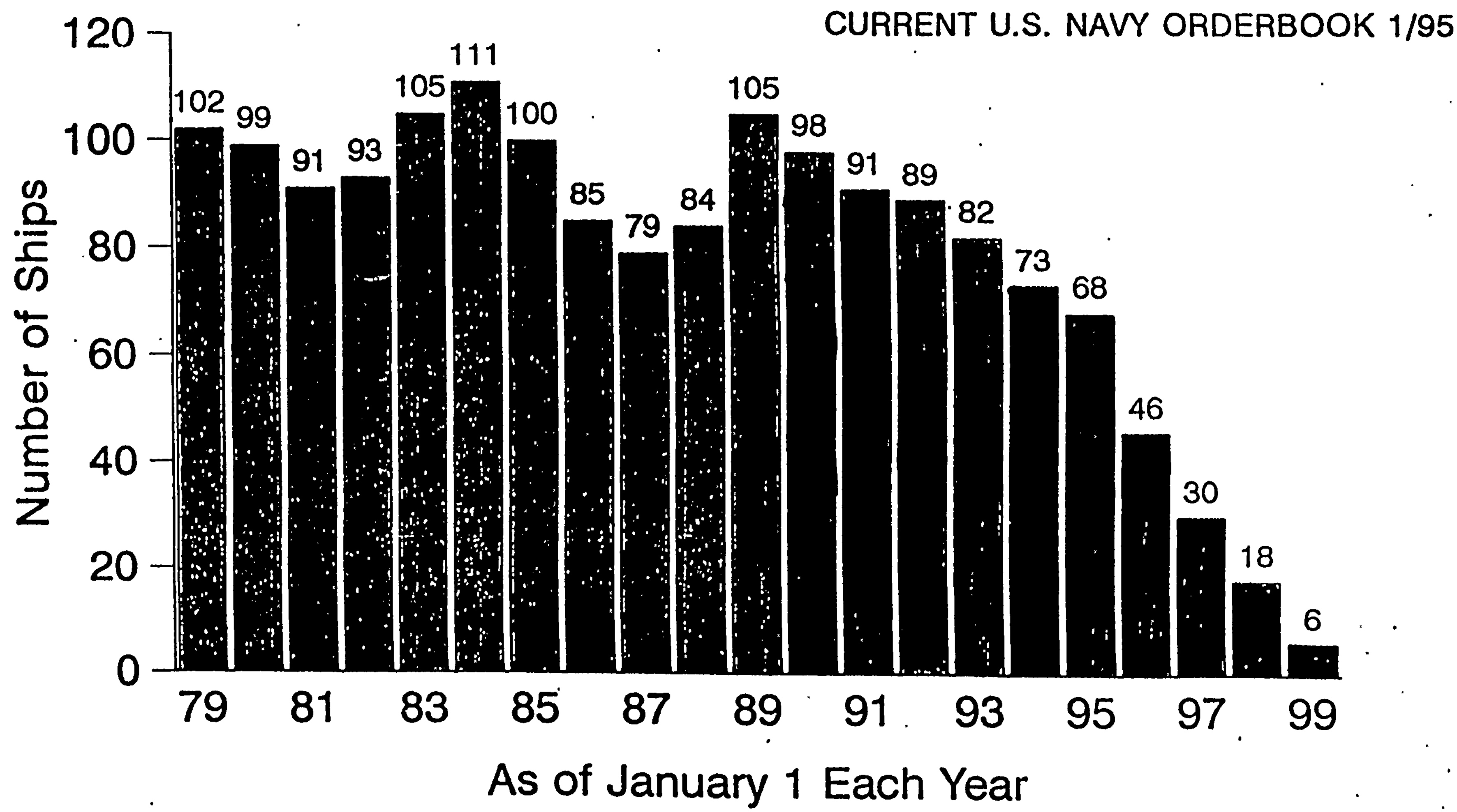
RESULT IS FIERCE COMPETION AND CONTINUING PRICES BELOW COST. GOVERNMENT SUPPORT IN SOME FORM IS REQUIRED

IN MOST CASES PRICE IS 70% OF SHIPOWNER'S COMPETITIVENESS CONSIDERATION. DELIVERY TIME IS 20%

OF COURSE, DELIVERY TIME CANNOT BE SIGNIFICANTLY LONGER THAN THE INTERNATIONAL OFFERING

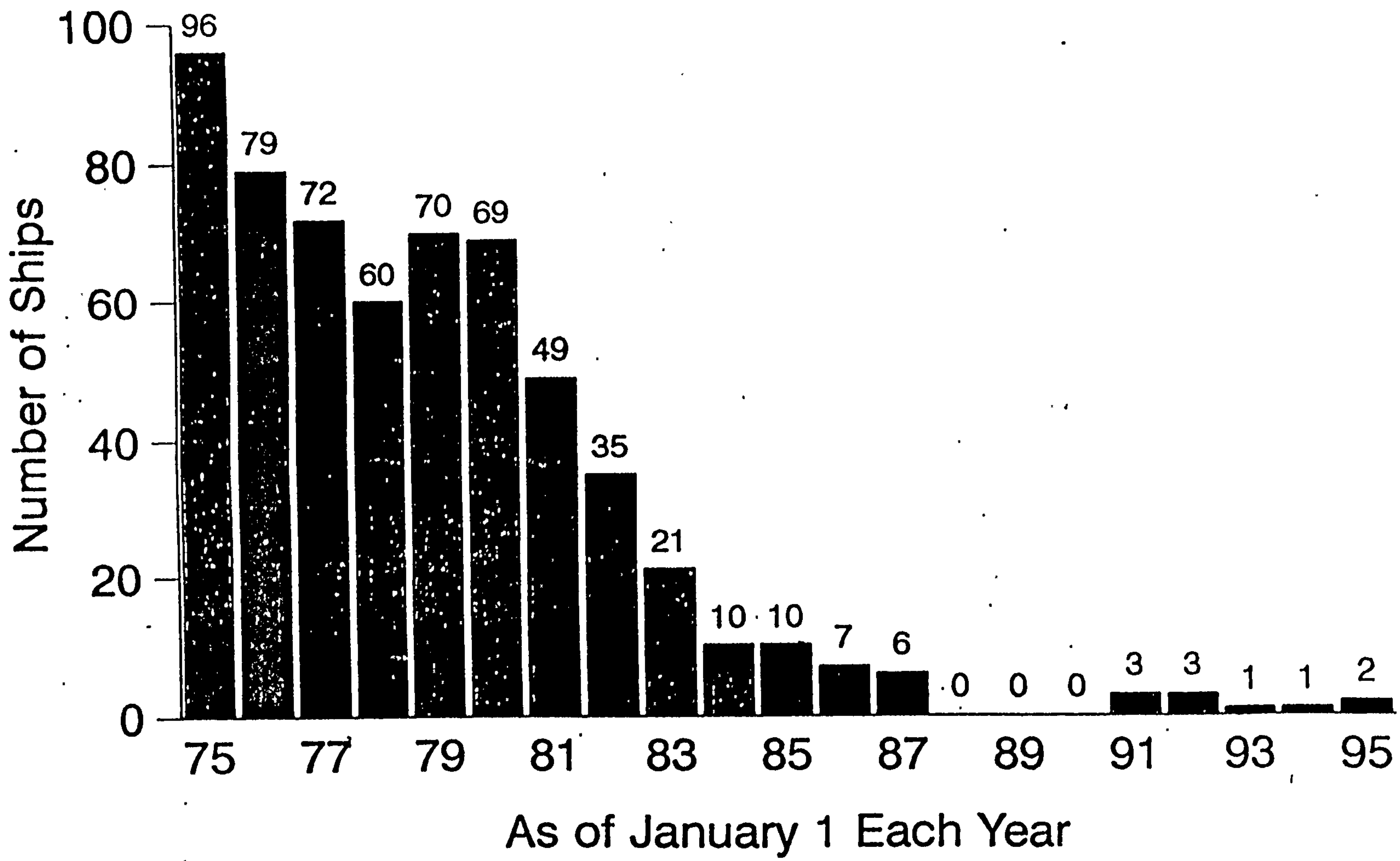
SHIPBUILDER'S DIRECT COST ISA COMBINATION OF PRODUCTIVITY AND LABOR RATE

PROBLEM: U.S. NAVAL VESSEL CONSTRUCTION ON DECLINE



Ships under Construction or on Order at U.S. Private Shipyards
1,000 Light Displacement Tons and Over

PROBLEM: COMMERCIAL U.S. SHIPBUILDING NOT MAJOR COMPETITOR INTERNATIONALLY



Ships under Construction or on Order at U.S. Private Shipyards
1,000 Gross Tons and Over
Source: Shipbuilders Council of America

WHERE ARE WE?

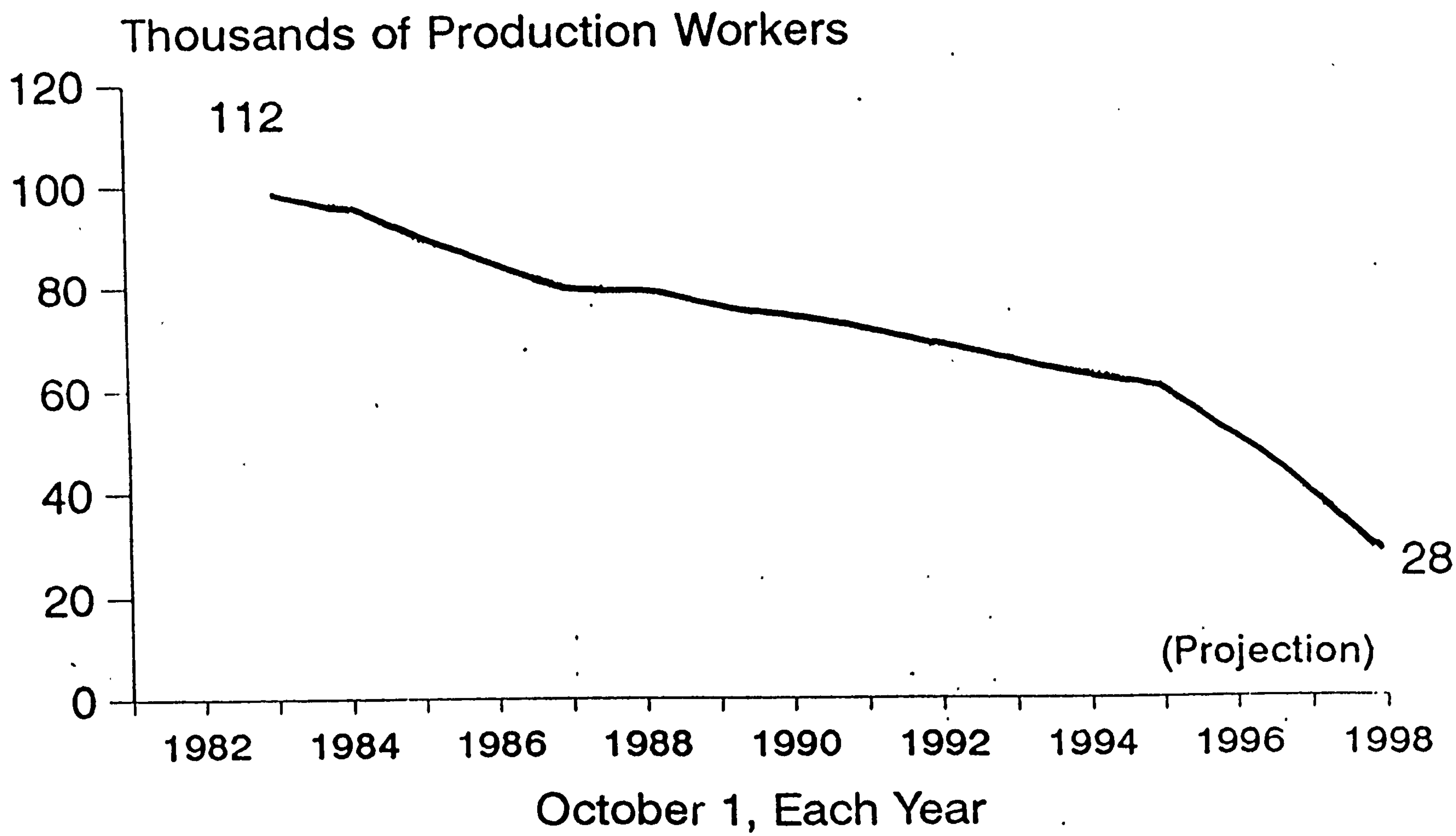
PRODUCTIVITY APPROXIMATELY HALF BEST WORLD PRACTICE

MATERIAL COST 30-50% HIGHER THAN INTERNATIONAL COMPETITORS

OVERHEAD HIGHER THAN INTERNATIONAL COMPETITORS

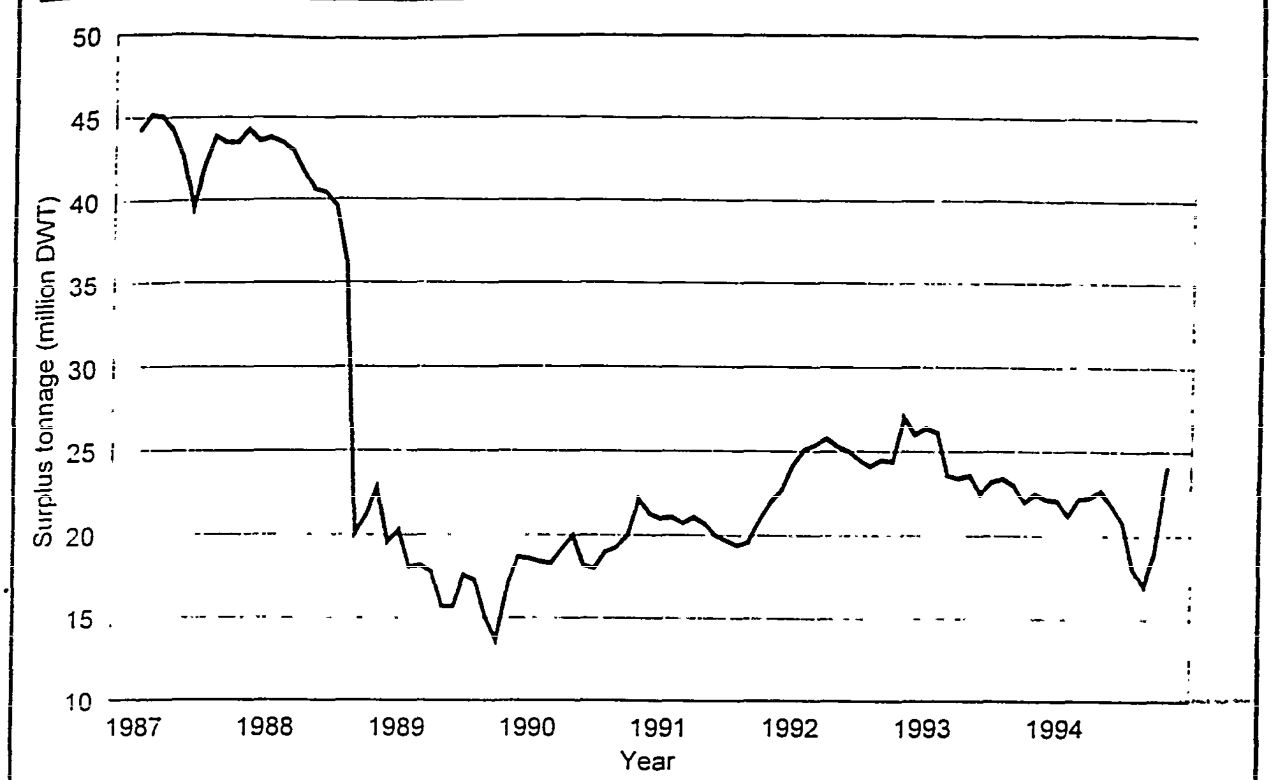
LARGE SHIPYARDS WANT TO BE DUAL PURPOSE SHIPBUILDERS

PROBLEM: U.S. SHIPBUILDING MANPOWER BASE ERODING

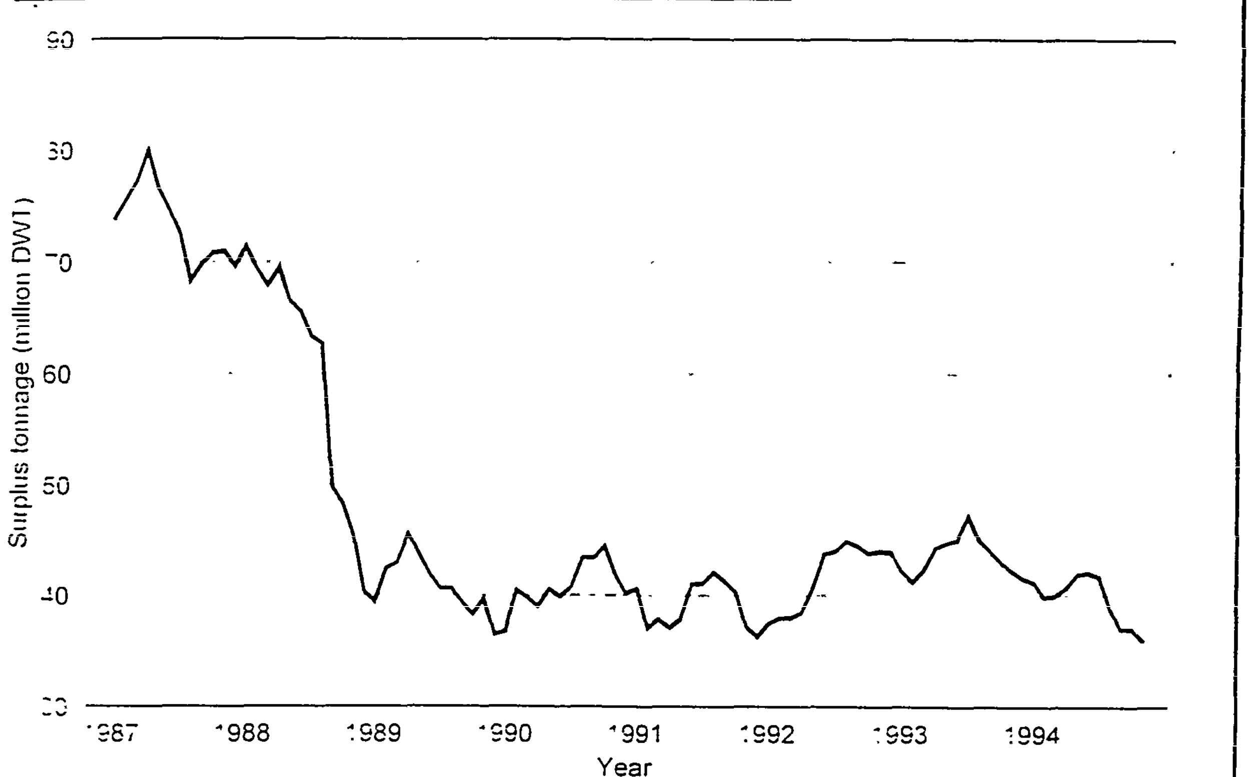


Source: Shipbuilders Council of America

BULKER SURPLUS TONNAGE



TANKER SURPLUS TONNAGE



UNDERSTANDING CHANGE

- IN THE PAST DECADE, 30 MILLION AMERICANS HAVE BEEN DISLOCATED BY RESTRUCTURING
- COMPANIES STILL ANTICIPATE THAT THEY WILL NEED To REDUCE THEIR WORKFORCE BY 15% (LEAN AND MEAN)
- THE FORTUNE 500 COMPANIES HAVE AXED 3.2 MILLION JOBS SINCE 1980
- IN THE PAST 5 YEARS 12000 U.S. COMPANIES HAVE CHANGED OWNERSHIP
- ABOUT 70% OF MERGERS FAIL

UNDERSTANDING CHANGE (Continued)

- MOST PEOPLE AND COMPANIES DO NOT WELCOME CHANGE

- CHANGE MUST BE MANAGED. IF LEFT TO ITSELF YOU DONT KNOW HOW IT WILL END AND YOU PROBABLY WILL NOT LIKE THE DESTINATION

- SOMETIMES CHANGE IS UNDERTAKEN ONLY WHEN SURVIVAL IS THREATENED

- OUTSIDE EVENTS USUALLY "TRIGGER" CHANGE, SUCH AS:
  - COMPETITORS MAKE A CHANGE
  - CUSTOMERS DEMANDS/EXPECTATIONS CHANGE
  - LEGISLATION CHANGES
  - HUMAN RESOURCE AVAILABILITY
  - EMPLOYEE EXPECTATIONS

UNDERSTANDING CHANGE (Continued)

- **FOUR TYPES OF CHANGE**

1. CHANGES IN TECHNOLOGY
   - INTRODUCTION OF CAD/CAM/CIM
   - NEW PRODUCTION PROCESSES
   - NEW FACILITIES
2. CHANGES IN PRODUCT
   - FROM MILITARY TO COMMERCIAL SHIPS
3. ADMINISTRATIVE CHANGES
   - ORGANIZATION STRUCTURE CHANGES
   - NEW MISSION STATEMENT
   - NEW PERFORMANCE APPRAISAL SYSTEM
4. CHANGES IN HUMAN RESOURCES
   - ORGANIZATIONAL BEHAVIOR INTERVENTIONS

Incremental Change	Radical Change
Continuous progression	Frame-breaking burst
Maintain equilibrium	Reach new equilibrium
Affect organizational part	Transform entire organization
Through normal structure and management processes	Create new structure and management
New technology	Breakthrough technology
Product improvement	New products create new markets

Source: Based on Alan D. Meyer, James B. Goes, and Geoffrey R. Brooks, "Organizations in Disequilibrium: Environmental Jolts and Industry Revolutions," in George Huber and William H. Glick (eds.) *Organizational Change and Redesign*, (New York: Oxford University Press, 1992); and Harry S. Dent Jr., "Growth Through New Product Development," *Small Business Reports*, November 1990, 30-40.

Transparency 93 (Exhibit 8.1)

Incremental Versus Radical Change

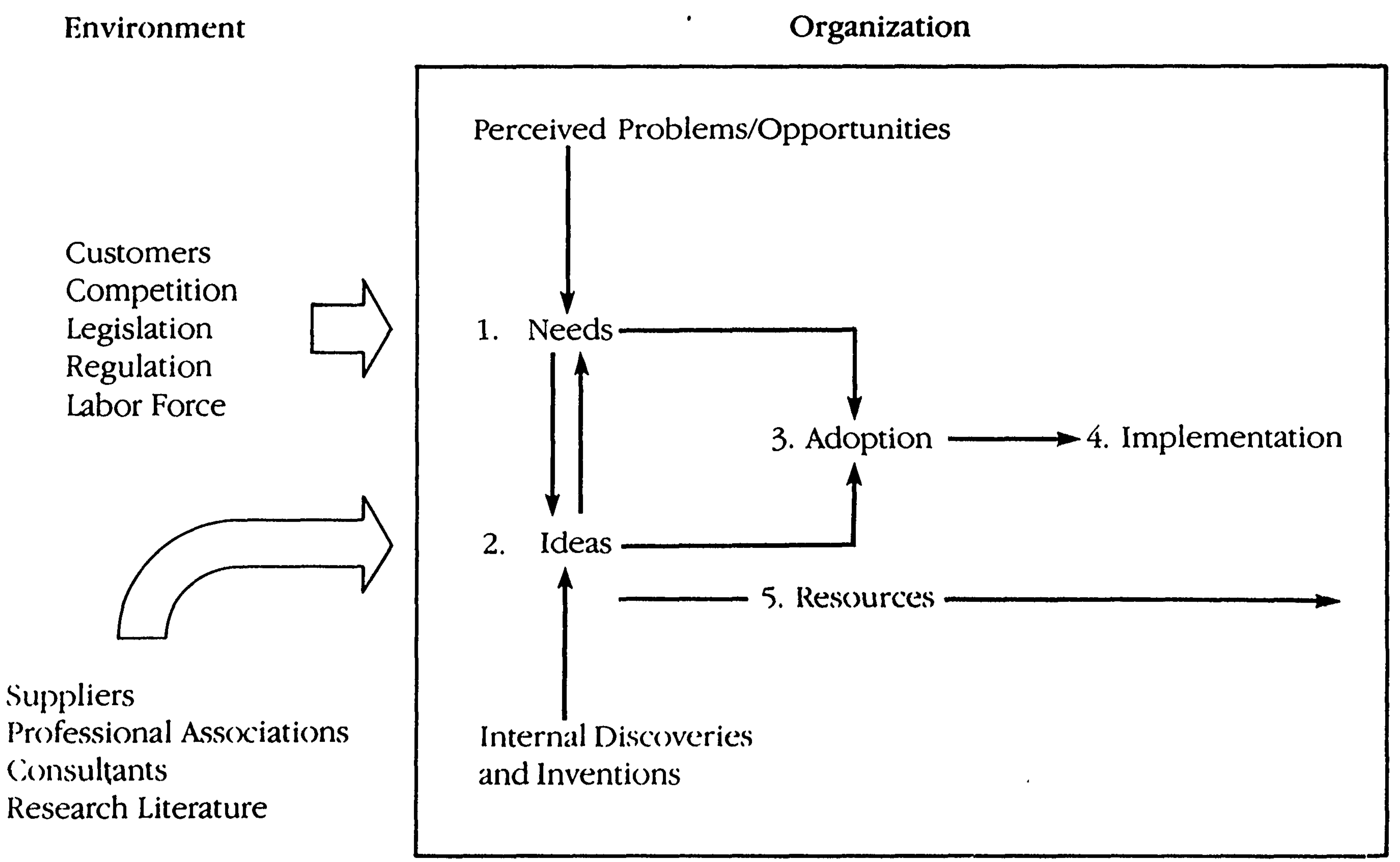
Exhibit 15-3: **Forces for Change**

External Forces

- Changes in the marketplace
  - Competitor actions.
  - Customer tastes and incomes.
  - Resources.
- Changes in technology.
- Changes in the environment.

Internal Forces

- Changes in processes.
- Changes in people.



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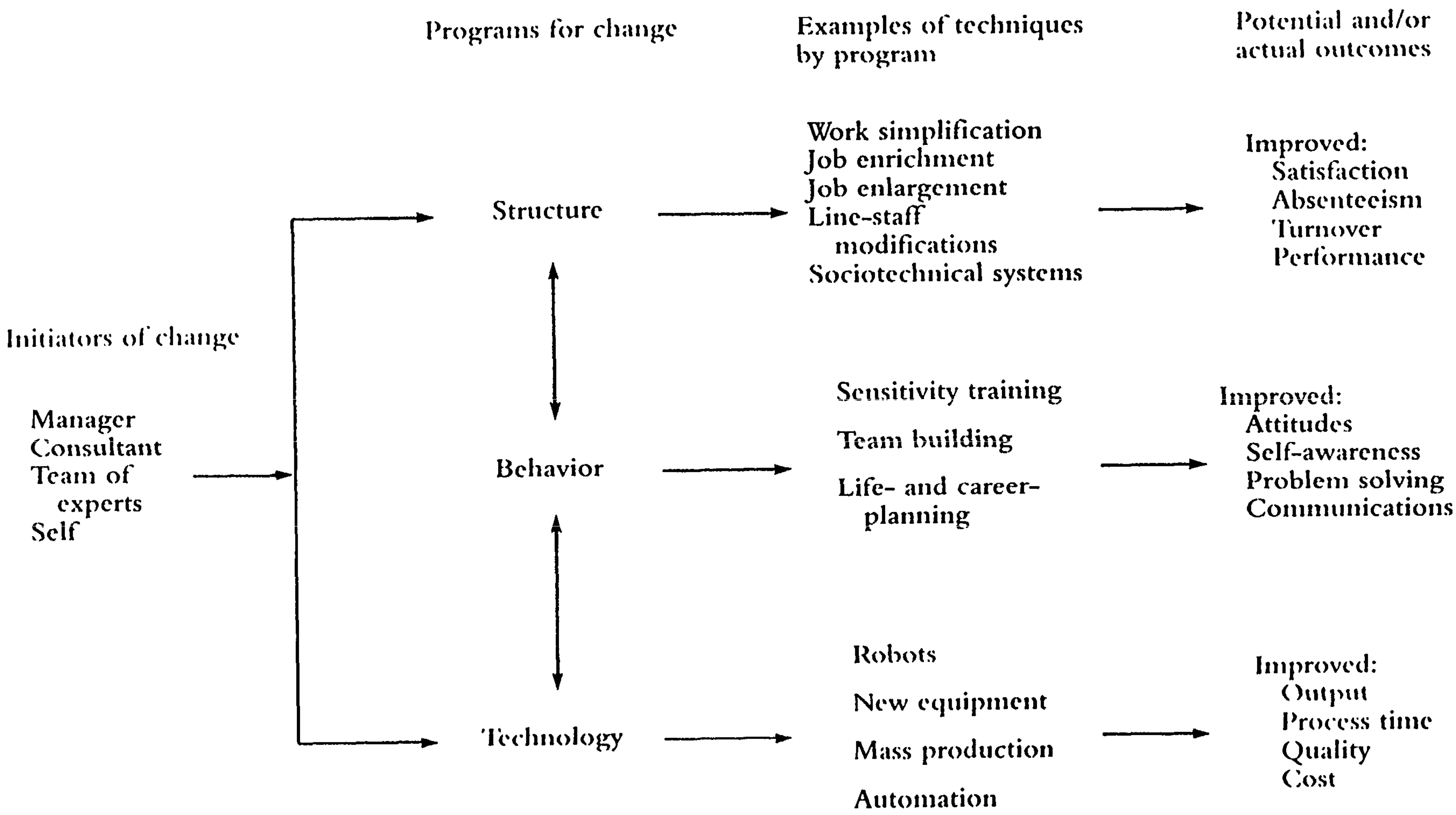
Typical Sequence in Ingredients of Successful Change

Figure 15-6: Selected Programs, Techniques, and Outcomes of Organizational Change



BARRIERS TO CHANGE

- MANAGEMENTS INABILITY TO RECOGNIZE NEED FOR CHANGE
- MANAGEMENTS INABILITY TO RECOGNIZE BENEFITS
- LACK OF COORDINATION AND COOPERATION
- RISK SEEN TO BE TOO HIGH
- PERSONAL RESISTANCE TO CHANGE

WHY PEOPLE RESIST CHANGE

- PAROCHIAL SELF-INTEREST
- MISUNDERSTANDING
- FEAR OF THE UNKNOWN - FEAR OF FAILURE
- DIFFERENT ASSESSMENT OF NEED
- LACK OF TRUST BETWEEN THEM AND MANAGEMENT
- THREAT TO JOB SECURITY
- INERTIA - COMFORT WITH CURRENT SITUATION

OVERVIEW: OVERCOMING BARRIERS

Barriers are not always visible. Sometimes the barriers are mindsets, which con be exceedingly difficulty to change. The good news is that we can exert control over more of the barriers than we realize. The bad news is that it won't be easy, but achieving excellence seldom is.

The barriers must first be identified. Guessing or assuming what they are does not lead to identification. Recall the delivery service company that assumed customers were primarily interested in quick pickups and deliveries. They instructed their drivers not to talk to customers but instead to move briskly along their routes. Excessive customer complaints caused them to rethink their assumptions. Similarly, we cannot afford to assume that we understand the barriers preventing employees from doing their best work.

Decision makers attend to identifying barriers and also to determining the goals that the barrier may be preventing us from reaching. Those goals are also assessed to learn which most severely impact profitability, productivity, customer satisfaction, or any other focus the organization values.

Prioritization follows the identification. A governing body decides which barriers can and should be tackled first. Their decisions are then passed along to the teams that will do the work of barrier removal–unless, of course, the barriers are those within management's capacity to remove. (Quality gurus maintain that 85 percent of the causes of poor quality lie in the system, which management controls.) Careful assessment of barriers and the outputs they impact must precede the work of removal.

The barriers are not always physical barriers. We tend to think of outdated equipment, insufficient space, or disorganized files as the barriers that stand be tween quality and us. But the barriers can exist on many levels-psychological, personal, interpersonal, emotional, etc.

Teams depend on top management's wisdom and sensitivity in ascertaining which obstacles are preventing which values from being accepted. Their wisdom and sensitivity are also needed to help remove today's barriers that are preventing tomorrow's success.

Exhibit 15-1: Why Employees Resist Change

- Parochial self-interest.
- Misunderstanding and lack of trust.
- Different assessments of change.
- Low tolerance for change.

Table 15-1: Methods for Reducing Resistance to Change

Approach	Situational Use	Advantages	Drawbacks
Education + Communication	Where there is a lack of information or inaccurate information and analysis.	Once persuaded, people often will help with the implementation of the change.	Can be very time-consuming if many people are involved.
Participation + Involvement	Where the initiators do not have all the information they need to design the change, and where others have considerable power to resist.	People who participate will be commited to implenting change, and any relevant information they have will be integrated into the change plan.	Can be very time-consuming if participators design an inappropriate change.
Facilitation + Support	Where people are resisting because of adjustment problems.	No other approach works as well with adjustment problems.	Can be time-consuming, expensive, and still fail.
Negotiation + Agreement	Where someone or some group will clearly lose out in a change, and where that group has considerable power to resist.	Sometimes it is a relatively easy way to avoid major resistance.	Can be too expensive in many cases if it alerts others to negotiate for compliance.
Manipulation + Co-optation	Where other tactics will not work or are too expensive.	It can be relatively quick and inexpensive solution to resistance problems.	Can lead to future problems if people feel manipulated.
Explicit + Implicit Coercion	Where speed is essential, and the change initiators possess considerable power.	It is speedy and can overcome any kind of resistance.	Can be risky if it leaves people angry at the initiators.

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HOW TO INCREASE CHANCE OF SUCCESS

- PLAN AND MANAGE THE CHANGE
- COMMUNICATE NEED FOR CHANGE BEFORE IMPLEMENTING ANY CHANGES
- MINIMIZE THE NEGATIVES AND MAXIMIZE THE POSITIVES
- INVOLVE THE PEOPLE WHO WILL BE IMPACTED BY THE CHANGE IN THE CHANGE PLANNING AND PROCESS
- USE CHANGE TEAMS
- PUT A RESPECTED MANAGER IN CHARGE OF THE CHANGE AND BUILD TRUST
- MAKE SURE YOU DO NOT DESTROY TRUST BY STUPID ACTIONS
- MAINTAIN PERCEIVED FAIRNESS IN DEALING WITH ALL EMPLOYEES
- VISIBLY REWARD THOSE WHO SUPPORT THE CHANGE

I. PREPARATION

Before the change, whenever possible, follow these steps:

- ☐ Prepare your employees. Let them know what is happening ahead of time. Telling them too far ahead of time is not always better (for example, telling people 8 months before a change only leaves time for anxiety to build up).

- ☐ Describe the change as completely as you can. How do you see the change affecting individual employees and the work group as a whole? Identify who will be most affected and approach them first.

- ☐ Research what happened during the last change. Does your group have a positive history of their ability to manage change, or was the last change traumatic? Learn from past experience and let this background influence your current actions.

- ☐ Assess the organizational readiness of your team. Are they ready to undertake a change? An organization or group that isn't mentally and emotionally prepared will tend to stay in denial, rather than accept the change and move on.

- ☐ Don't make additional changes that aren't critical. People need all the stability they can get during change. Don't change the payroll dates, the working hours or cafeteria procedures when you are making large-sale organizational changes. Change the most important things one at a time.

IV. IMPLEMENTATION

Take clear, flexible action to accomplish these goals:

- ☐ **Provide appropriate training in new skills and coaching in new values and behaviors.**
- ☐ **Encourage self-management. Inform each person that he or she is accountable for some aspect of the change.**
- ☐ **Give more feedback than usual to ensure that people always know where they stand.**
- ☐ **Allow for resistance. Help people let go of the "old." Prepare to help those having special difficulty making the adjustment.**
- ☐ **Give people a chance to step back and take a look at what is going on. Keep asking, "Is the change working the way we want it to?"-**
- ☐ **Encourage people to think and act creatively.**
- ☐ **Look for any *opportunity* created by the change.**
- ☐ **Allow for withdrawal and return of people who are temporarily resistant. Don't cross off people as irretrievable.**
- ☐ **Collaborate. Build bridges from your work group to other work groups. Look for opportunities to interface your activities.**
- ☐ **Monitor the change process. Conduct surveys to find out how employees are responding to the change.**

V. REWARD

Share the gains:

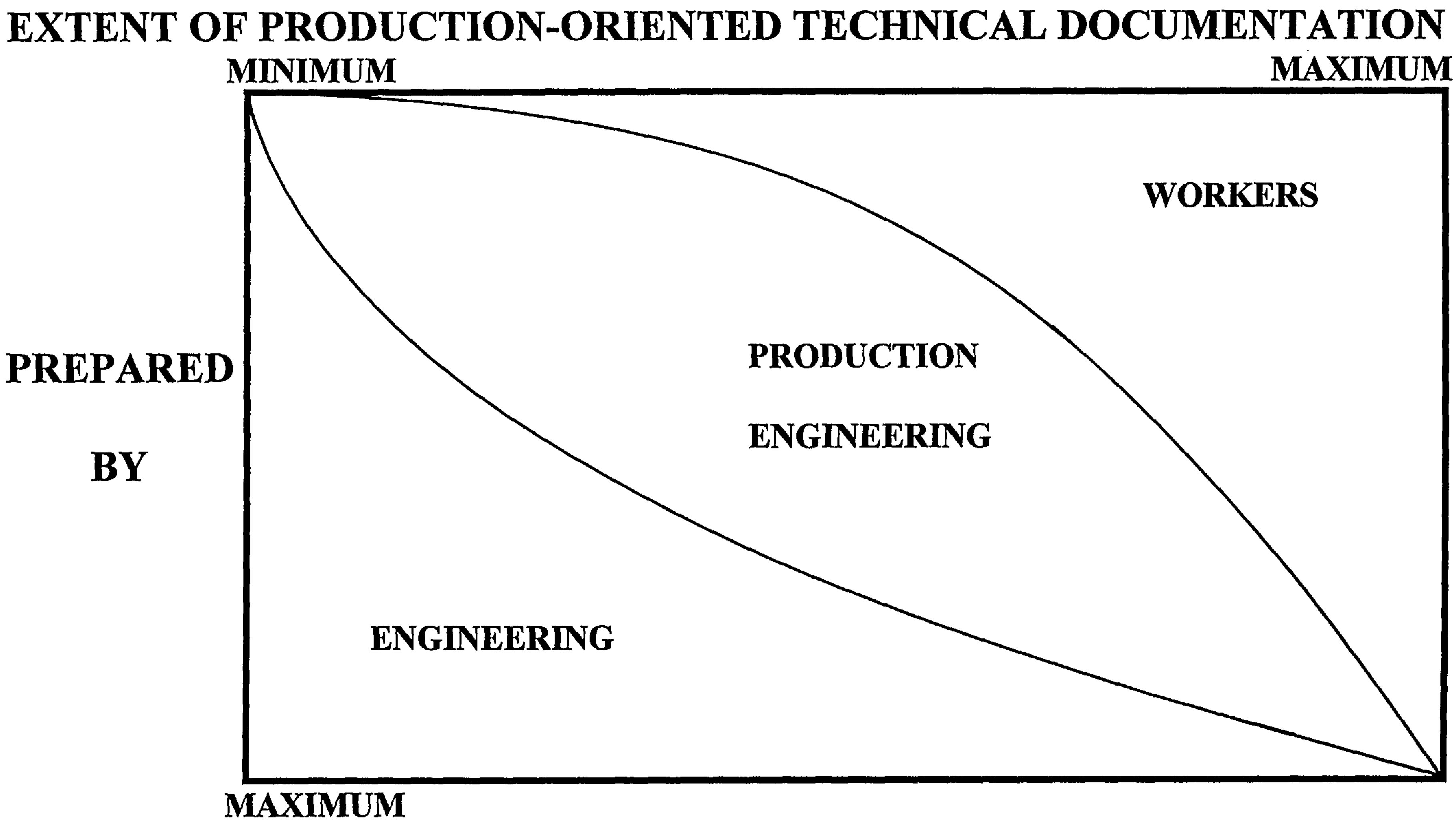
- ☐ **Create incentives for special effort. Celebrate those who lead the change. Give one-time bonuses to groups who have come through the change smoothly.**
- ☐ **Celebrate by creating public displays that acknowledge groups and individuals who have helped make things happen.**

NATIONAL SHIPBUILDING RESEARCH PROGRAM

PRODUCTION ENGINEERING

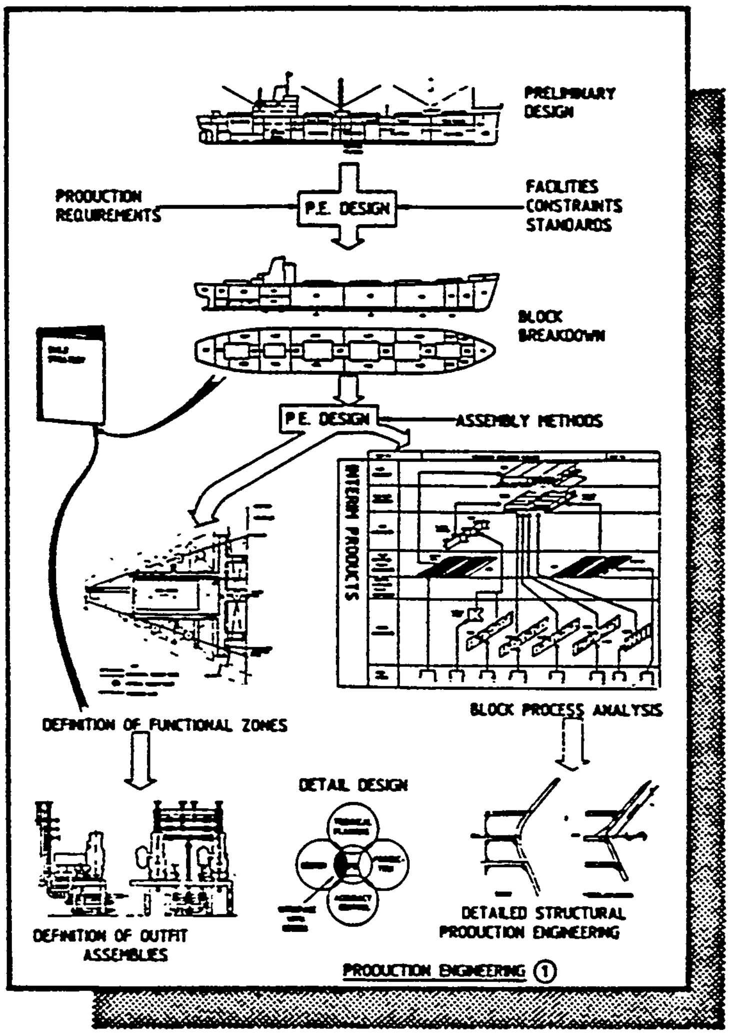
DESIGN FOR PRODUCTION INTEGRATION

WHERE IS THE PRODUCTION ENGINEERING?



PRODUCTION ENGINEERING (1)

DESIGN/PRODUCTION ENGINEERING INTERFACES



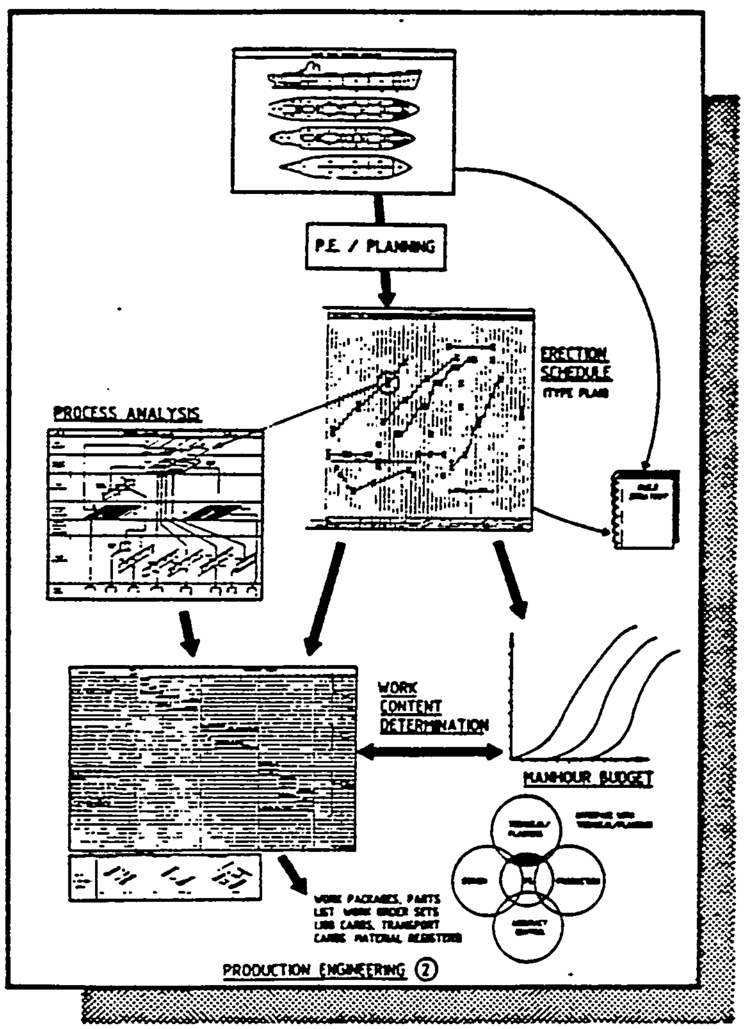
Implementation of the Shipbuilding Strategy in order to:

- prepare a design that reflects production facilities and methods
- design out needless work
- ensure separation of steel and outfit work to give manufacturing flexibility
- increase STANDARDISATION.

PRODUCTION ENGINEERING (2)

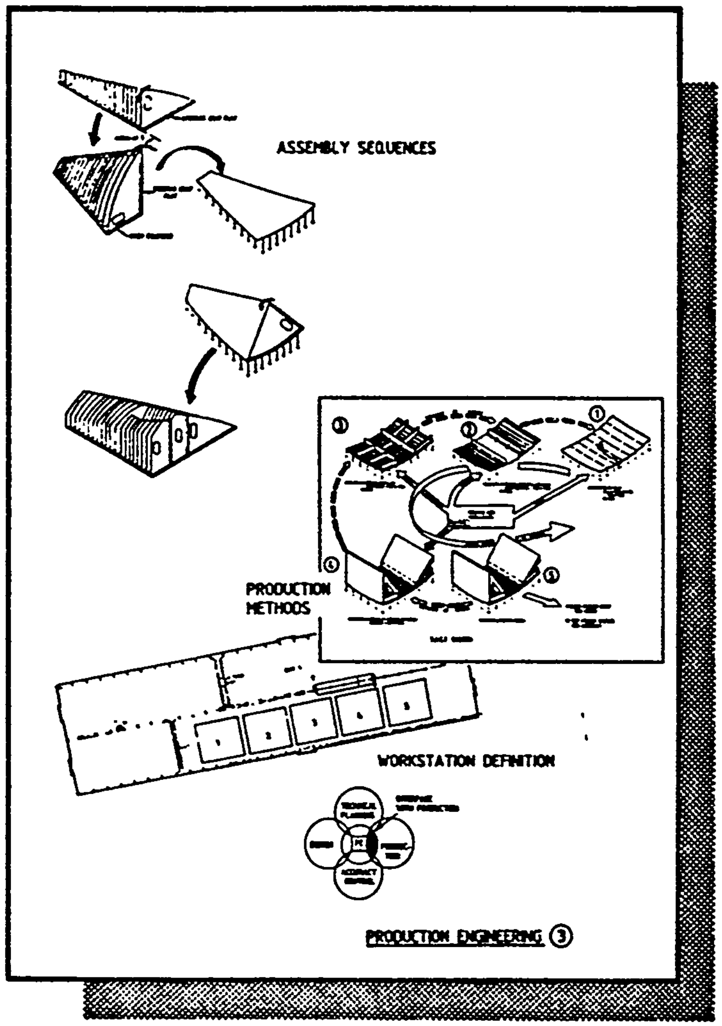
PRODUCTION ENGINEERING/PLANNING INTERFACES

- Definition of process and methods standards to allow simple but effective planning systems to be implemented.
- Production SIMPLIFICATION.



PRODUCTION ENGINEERING (3)

PRODUCTION ENGINEERING/PRODUCTION INTERFACE

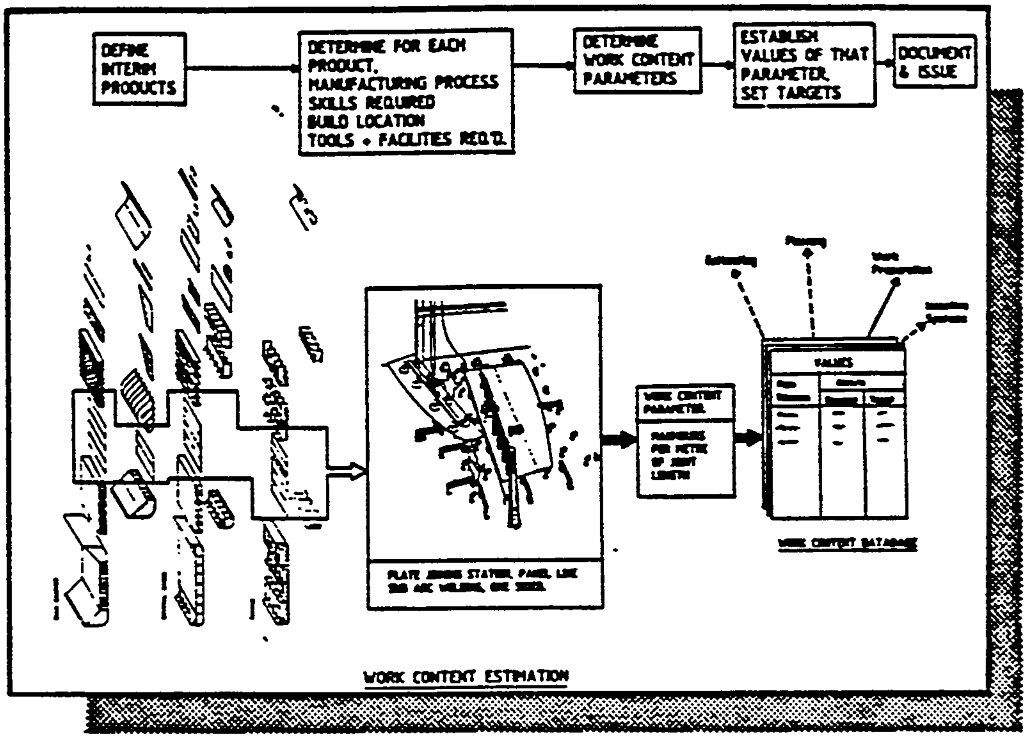


Definition of optimum methods based on existing facilities and equipment to maximise flowline production.

Identification of facility and equipment changes that will improve production methods and lead to increased SPECIALISATION

Comnunication of change to technical and planning function.

WORK CONTENT ESTIMATION

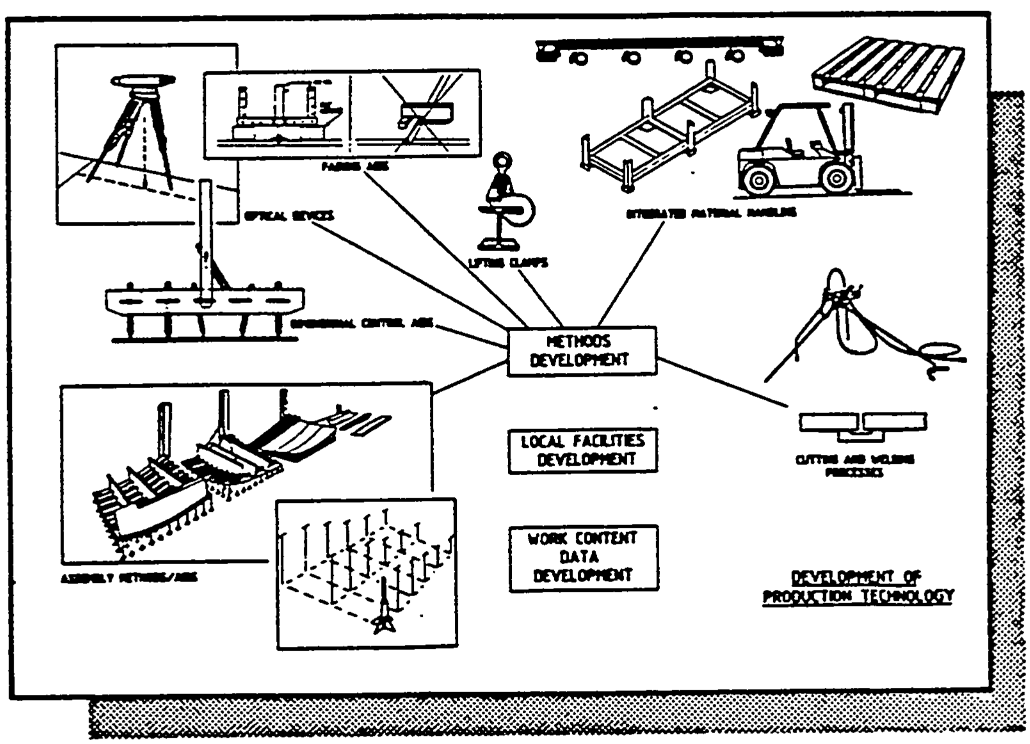


Work content data related to production workstations and processes will make it possible to:

- carry out workstation loading
- answer questions like:
  - what has been produced?
  - what should have been produced?
  - what has it cost?
  - what should it have cost?
  - what will the final outcome be in terms of time and cost?

DEVELOPMENT OF PRODUCTION TECHNOLOGY

- Constant appraisal and improvement of production methods and techniques.



In analyzing this problem in steel production a flow chart was made registering the movement of more than 48,000 pieces of steel (Figure 8). Production targets were thereupon subdivided workshopwise into items produced within the required period of time. Planning and follow up was based upon parameters best correlated to work content, (schematically shown in Figure 9), and previously registered manhours and the systems based thereupon were more or less disregarded.

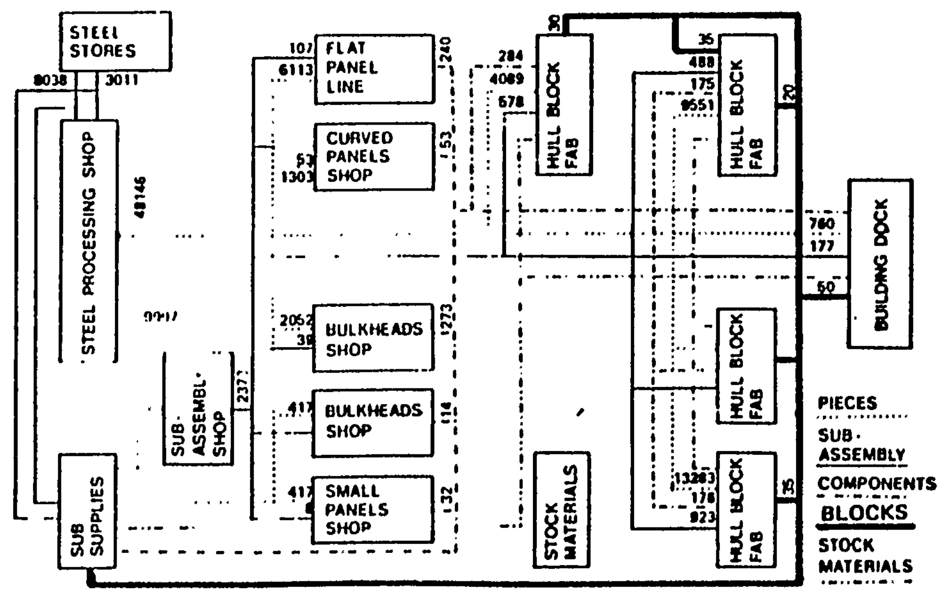


FIG. 8 MATERIAL FLOW CHART

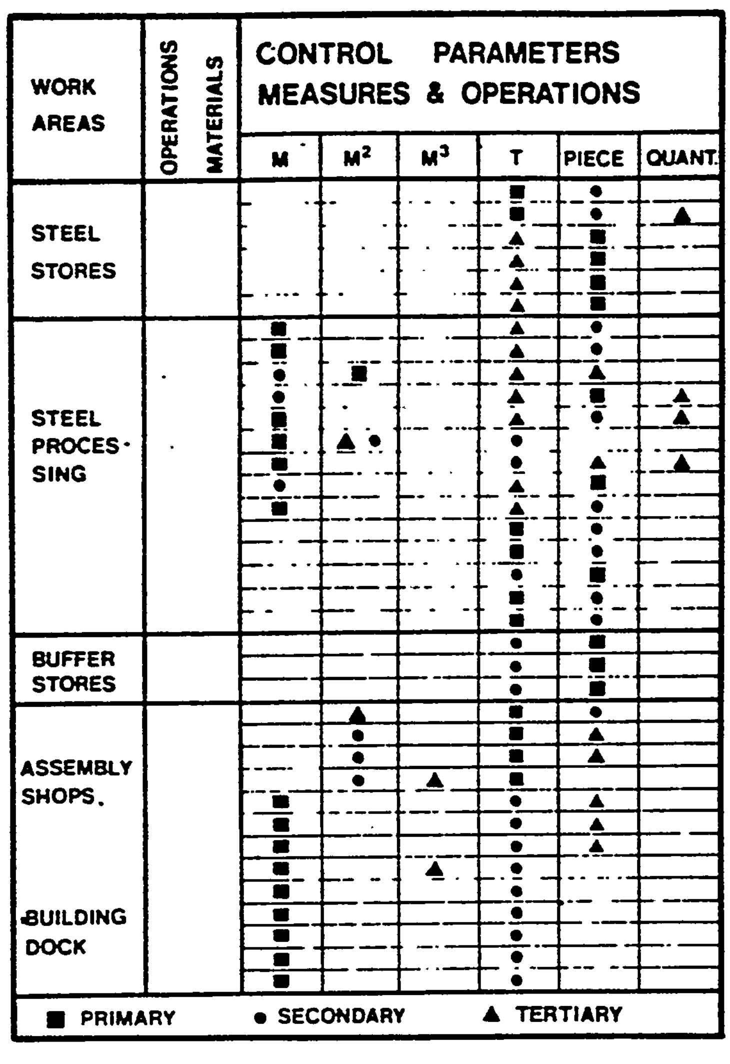


FIG. 9 PRODUCT FLOW PARAMETERS

Production complexity for the bulk carriers in terms of manhours, production time and production area required is shown in Figure 11. As may be forseen the fore and aft part is more labour intensive and requires longer production time, more crane coverage, supply service etc., than the parallel midship. This longer production time requires more space.

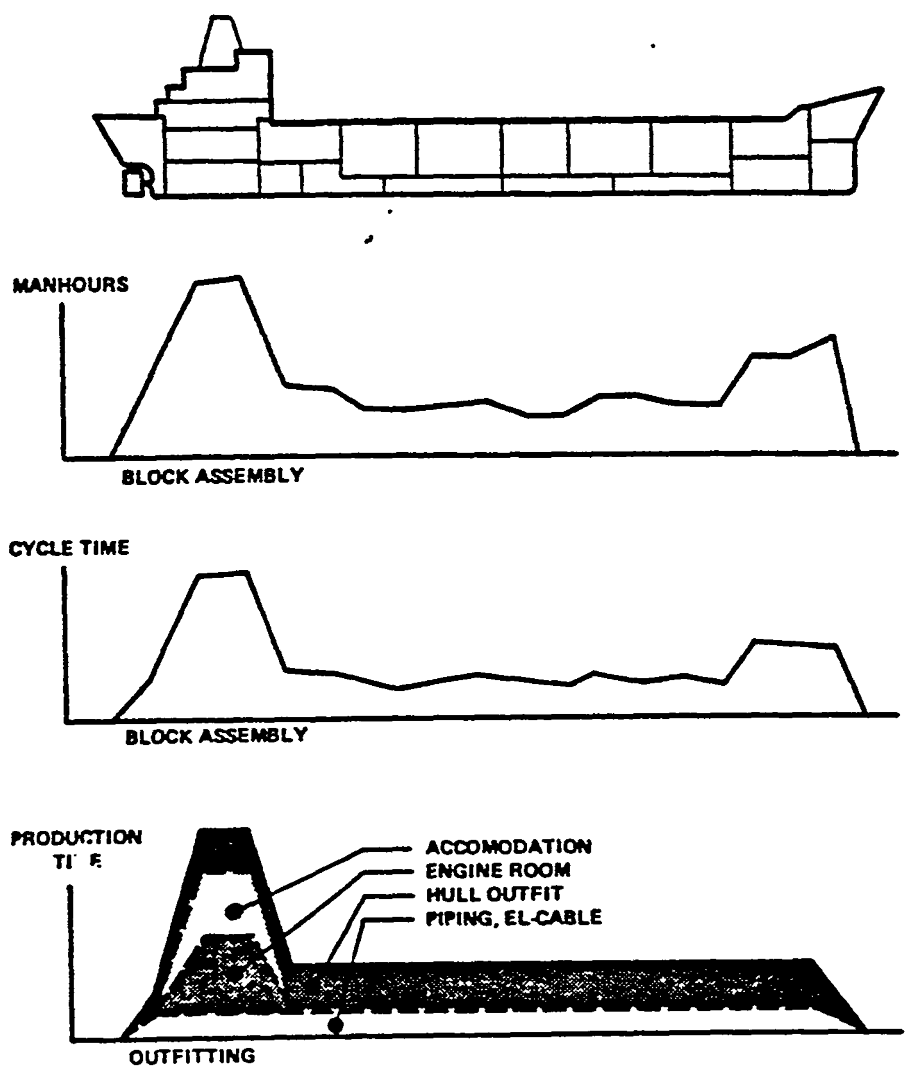


FIG. 11 LOAD DISTRIBUTION FOR BC50

Concluding these evaluations yard status as per 1972/73 is shown in Figure 10. The production capacity was restricted to 4 ships per year and the future target of 7 1/2 ships per year could be met only by the building dock.

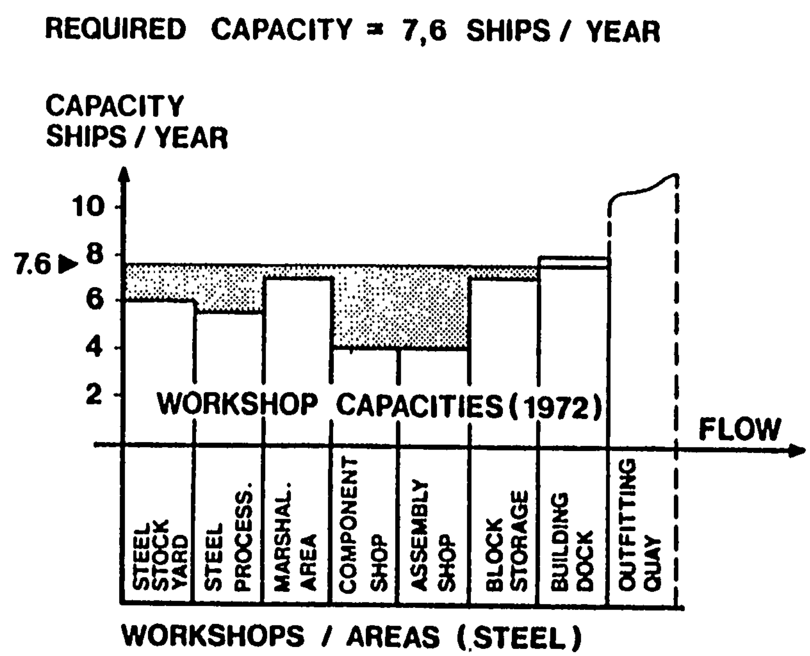


FIG. 10 CAPACITY PROBLEM BOTTLENECK

Cycle period is to be reduced, then average steel block weight and area under crane coverage must increase to facilitate increased throughput (as shown in Figure 12). The load on facilities can be levelled by dispersing work content to other and earlier stages. As shown by module production, Figure 13, or by tendem production, Figure 14, where labour intensive part of engine room for next ship is built in a separate location at the same time and building period as the ship to be launched.

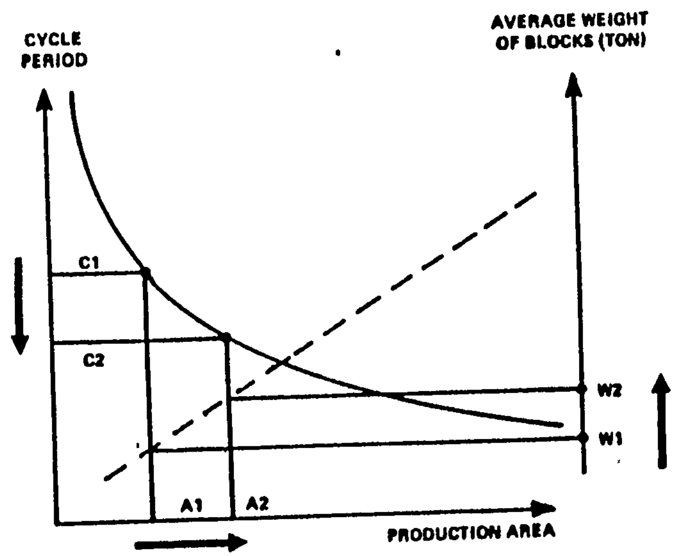


FIG. 12 AREA/ACTIVITY DURATION/WEIGHT OF BLOCK

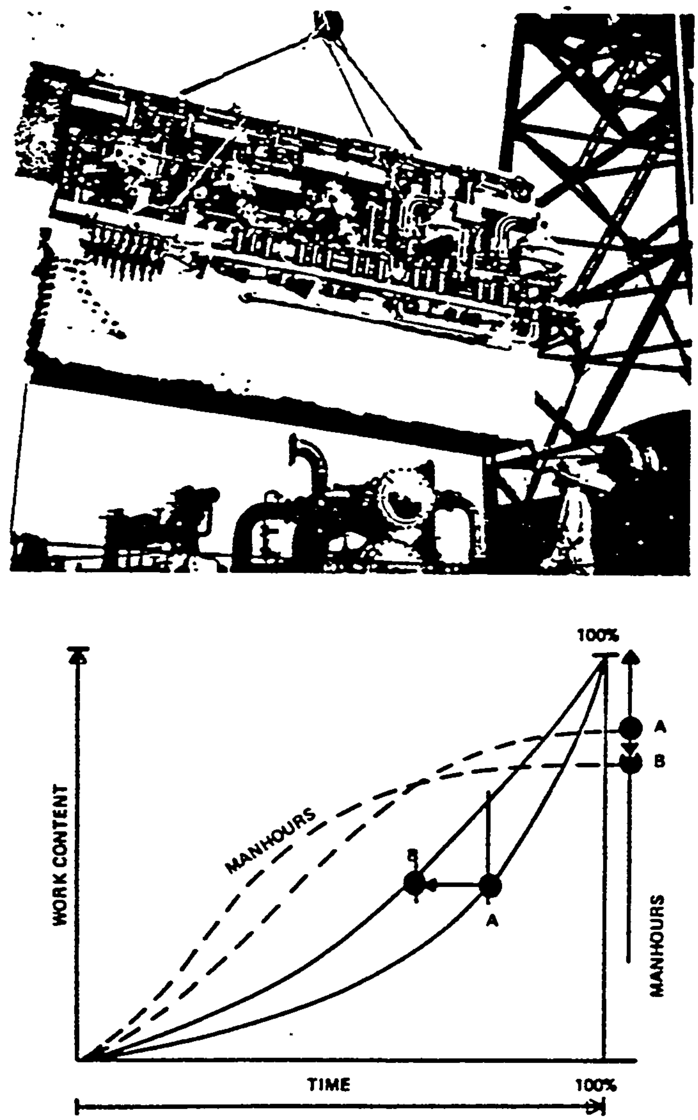


FIG. 13 MODULE PRODUCTION

Figure 15 indicates how the ships were simplified by removing forecastle and poop, box shaping superstructure, modulizing engine room, reducing number of blocks, standardizing hold and hatch sizes as well as double bottom height.

52.000 DWT		
STEEL WEIGHT	7,900	TONS
NO. OF STEEL PLATES	3,200	
NO. OF SHAPES	8,000	
NO. OF HULL PIECES	51,000	
WELD LENGTH	155	MILES
PIPE LENGTH	24	MILES
ELECTRICAL CABLES	25	MILES

60.000 DWT		
STEEL WEIGHT	9,000	TONS
NO. OF STEEL PLATES	2,500	
NO. OF SHAPES	4,000	
NO. OF HULL PIECES	35,000	
WELD LENGTH	125	MILES
PIPE LENGTH	16	MILES
ELECTRICAL CABLES	26	MILES

FIG. 15 SIMPLIFICATION OF BULK CARRIER DESIGN

Every part of the ship was redesigned with the purpose of making work easier even if steel weight had to be slightly increased. Figure 16 shows an example as to how such simplifications can be made on scantlings in double bottom, hopper and topwirg tanks.

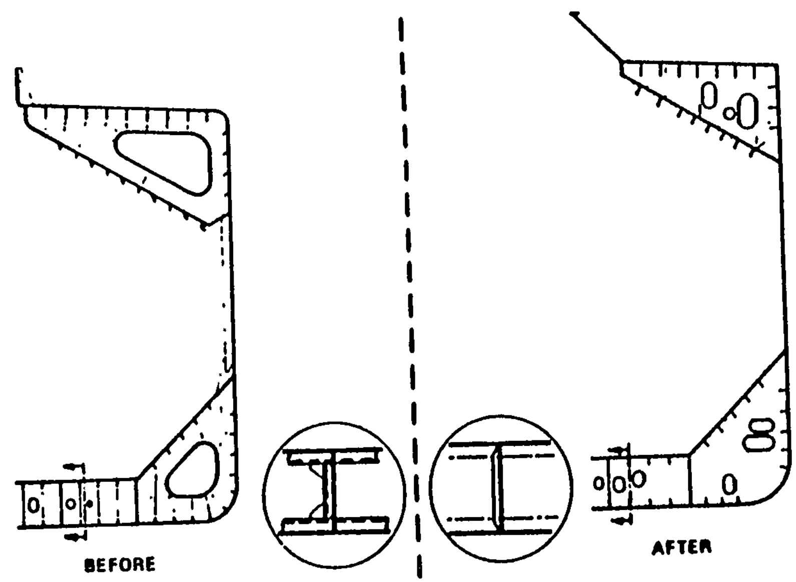


FIG. 16 MIDSHIP SECTION

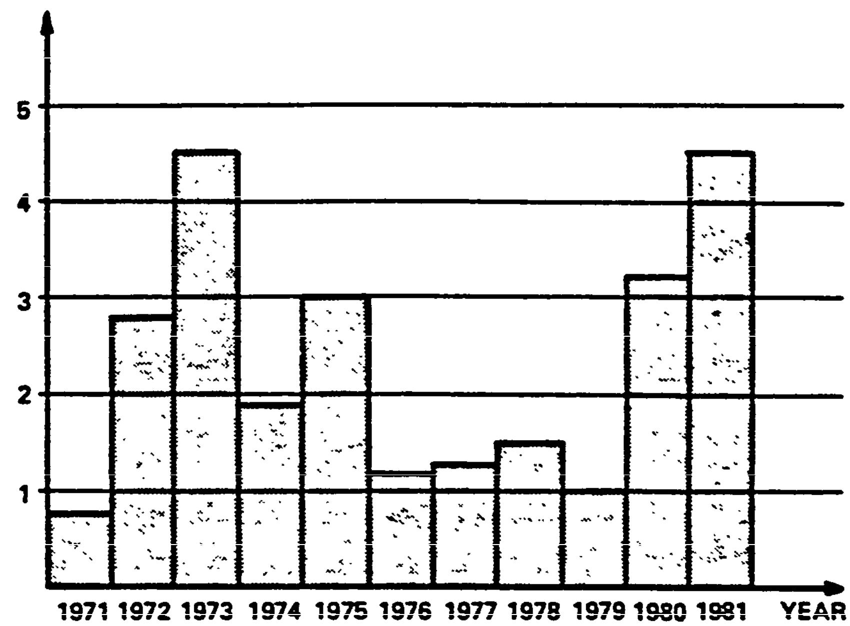


FIG. 19 INVESTMENT % OF TURNOVER

Adequately covered with the basic prerequisites of space and crane coverage, our investments policy has since been limited to purchase of minor equipment (such as automatic welding machines) and to development of new software systems. We do not believe in investments in sophisticated numerically controlled equipment for the early steel production stages, such as plate storage handling and plate and profile cutting workshops, for the simple reason that in a production process where 70% of the manhours are consumed in assembly halls and building dock and 20% in subassembly, limited effect on total picture can be obtained by substantial investments on reduction of the last 10% of manhours consumed in the plate handling and cutting process.

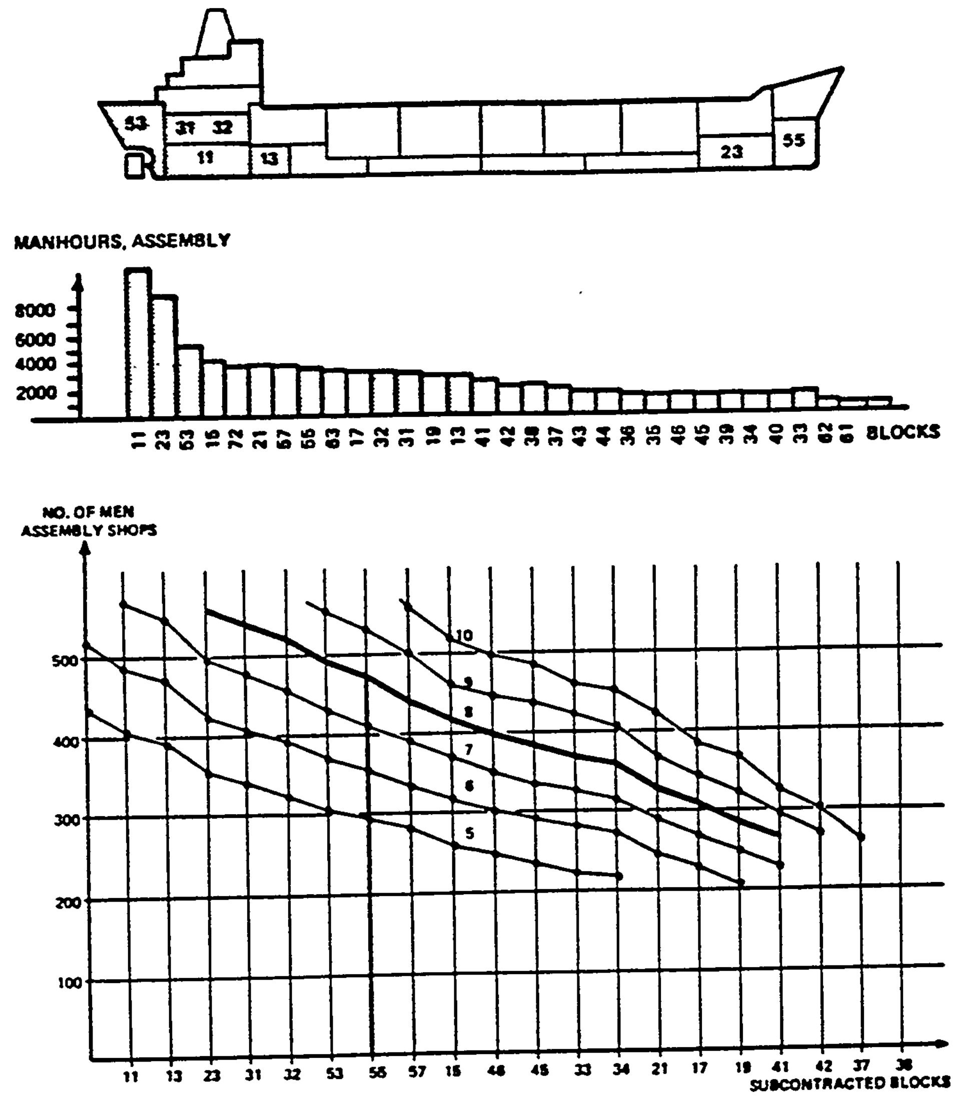


FIG. 20 & 21 NO. OF BLOCKS SUBCONTRACTED FROM ASSEMBLY SHOPS WITH EFFECT ON PRODUCTION FLOW FROM ASSEMBLY SHOPS

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PRODUCTION METHODS
IMPLICATIONS OF PRODUCTION ENGINEERING

Contents

1. REVIEW OF SHIPBUILDING PRODUCTION METHODS

When one reviews shipbuilding production methods it is natural to focus on the product, the ship, and the methods used in construction. To the shipbuilding industry critics, only isolated cases of improvement are worthy of comment and little has been achieved in Western Europe over the last thirty- years. After all the shipbuilding industry continues to drag its heels and employs technology which is out of date when compared to Far Eastern Shipyards. Yet the products produced in the Far East, to all intents and purposes, appear to be the same as those produced in Western Europe.

To answer such criticism constructively it is necessary to examine the various factors which affect the product and the method,s employed during construction.

1.1 Product Design

The principal objectives in ship design remained unchanged for many years. Earning capacity, in the case of merchant ships, was and still is of paramount importance. Trade routes and ports of call placed limitations on ship dimensions while seasonal and perishable cargoes required speed to achieve high market prices. Tonnage measurement rules were a challenge to the naval architect who was skilled in developing designs to take advantage of such rules to achieve tonnage exemption. Such developments gave birth to Shade Decks, Awning Decks, Shelter Decks, Turret Decks, Trunk Decks and Raised Quarter Decks; those striving for improvements in underwater forms sought solutions from Maier, Yorkevitch, Arc and Monitor forms. Sheer, camber, rise of floor, tumble home and cut up survived for many years as desirable features. Counter and cruiser sterns also had their periods of popularity. Many design features were developments of previous features which had been found to be advantageous to the shipowner in the operation of the vessel.

Propulsion systems have undergone major developments not only from sail through paddles to screws and vanes but through engine types burning a variety of fuels. Most engineering developments. have evolved for economic reasons with the exception of special operational requirements as in the case of warships.

Accommodation has changed not only with fashion but with legislation and international standards of safety. Reduction in crew numbers can also be regarded as an economic development in terms of operational costs.

Port handling facilities have changed radically in the last thirty years such that rigging, as it was known, has disappeared and has been replaced in some instances by deck cranes.

The ship types required by shipowners have always been a function of the profitability of trade routes and cargoes or in the case of warships, defence policy during peace the. When times were good shipbuilders made handsome profits, when times were bad they incurred staggering losses. In the good times multi-ship orders were common, often for 'selected' owners, and in the bad times one had to depend upon friends for ship orders of varied types. In such circumstances the economics of shipbuilding were difficult to understand. This was in no small way due to the secrecy surrounding shipbuilding deals which were strictly confined to the boardroom.

It is not the purpose of this paper to dig up the past but rather to look to the future. However, to do so it is important to determine the current state of the art.

Merchant shipbuilding has been at the mercy of international economic trends for years and will continue to be so. Are there any lessons to be learnt from the past? Will the industry in Europe continue to stagger on from crisis to crisis for the next hundred years or will it cease to exist? Over the past ten years certain trends have been emerging which are indicative of change.

1.2 Facility Development

Shipyard facilities have changed due to sub-contract policies, material-changes and technology developments. A range of new shipyard layouts have emerged ranging from conversions to new ship factories. In an attempt to reduce overhead costs and minimise capital investment, manufacturing capabilities in shipyards have been reduced to a minimum by sub-contracting the manufacture of equipment previously made in the shipyard. Gone are the foundries, brass shops, boiler shops and engine shops. Tinsmiths, coppersmiths and blacksmiths are only names which linger on by tradition.

Many shipyards are only concerned with steel component manufacture, assembly and installation. Only in the new shipyards did the methods noticeably change. Traditional shipyards which entrenched-with a large sub-contract policy still tended to process steel material, construct the hull and then hand it over to the engineering and outfit installation teams for completion. But in recent times even some of the purpose built shipyards, designed to produce

series ships have closed due to economic pressures. The survivors who are in the best financial state are those who are capable of tackling a product mix which ten years ago would have been considered suicide. To achieve this requires a new look at the product, the facilities and the production methods employed.

It is of interest to note that one hundred years ago William Pearce achieved a turnover of £600,000 in a year while building cruisers, destroyers, corvettes, gun boats, despatch vessels, passenger vessels from five hundred to seven thousand four hundred Gross Reg. Tons, yachts and fishing vessels at the Govan Shipyard in Glasgow. All built using the same techniques and equipment on inclined construction berths, open to the elements. Only the machinery shops were totally enclosed, the plate and bar working shops were open at the sides. Around this time, at least two shipyards had covered berths, Swan Hunter on Tyneside and John Brown on Clydeside. These covered berths survived into the 1950's.

1.3 Technology Development

The development of technology was traditionally brought about through the mechanisation of process equipment, craft skills, material handling, environmental protection and planning.

The introduction of welding and increased crane lifting capacity brought about pre-erection assembly. For steelwork a form of flow process developed from material treatment to component manufacture, sub-assembly, unit assembly and finally erection. In many shipyards unit assembly was still carried out in the open and therefore subjected to weather conditions.

Plate cutting techniques improved with the introduction of optical burning machines and changed lofting from a manual full scale function to an office job drawing plate parts to 1:10th full size.

Welding technology continued to advance and shipyards adopted semi-automatic and automatic welding processes which could be put to advantage in a protected environment. Coupled with improved material handling equipment, vacuum and magnetic lifting beams attached to cranes, these welding processes were put to good use in producing flat stiffened panels. Mechanised panel lines naturally followed.

Little improvement in technology was seen in the outfit manufacturing areas due to most of this work being sub-contracted. The skills which existed in these areas were retained but only used during

installation of outfit items on board ship. In many shipyards where a change of product coincided with a sub-contract increase, a surplus of skilled outfitting labour caused an imbalance in the work-force. This was particularly noticeable in shipyards which carried a high proportion of outfitting labour required for passenger ships and warships. The demand for these ships declined and was replaced by orders for tankers and bulk carriers where the balance of labour required was quite different.

Outfit installation in some ways did change. The coming of the airless spray equipment for paint application increased the efficiency and quality of painting but wrecked havoc with the working environment. Sophisticated equipment and machinery controls required different skills to be employed on electrical installation work. If, these skills were not readily available, this work was usually sub-contracted or became part of the suppliers contract.

With the mechanisation of process equipment craft skills have diminished and been replaced by operative skills.

Materials and substances used in shipbuilding have changed markedly over the last fifteen years, notably insulation, paints, pipe materials, accommodation bulkheads and deck coverings. Some materials have improved not only the quality of the vessel but the ease with which they can be handled. Others, like some paint systems, impose restrictions and conditions on the shipbuilder far in excess of anything previously experienced.

The latest technological impact to be met with must surely be the computer. Since its introduction to the shipyards over twenty years ago it has steadily grown in importance. It has been particularly influential in the development of steelwork methods through the variety of computer aided design and computer aided manufacturing (CAD/CAM) software packages available. Methods in design offices right down to shop floor practices have been affected. The most important contributions computers have made to production methods is the mechanisation of manual drafting, the reduction in time to produce technical information and the accuracy of the information. Most CAD/CAM systems are based on a three dimensional co-ordinate system which allows 'envelopes' as well as single points to be described mathematically. This facilitates the identification of relationships between surfaces, fittings, equipment modules etc., and thus the ability to employ computer graphics and punched tape as the means of creating information for production purposes. This

can be used to good effect on all ship systems, particularly pipework.

The rate of change in technology in shipyards has certainly increased over the last ten years, in the product, facilities and methods applied. The most successful yards are those who have recognised the changes and have carefully managed this technology development.

To deliver ships on time at the minimum cost will continue to be a prime objective of any shipyard. To fulfil this objective, shipyards will have to keep abreast of technology developments, particularly if they have to cope with a varied product mix. It is believed that this will only be accomplished if the work content is reduced to common parts, irrespective of ship type, and the best technology is applied to the production of these common parts.

A recent ship factory development at. OKPO, South Korea, is employing this approach and, using a single facility, will produce a wide range of ships as well as offshore structures, floating power plants and processing plants. The facility is too large to be accommodated under one roof and therefore it has separate construction-halls for the production of pre-erection outfitted assemblies of different types which will be blocked together and erected in large portions, up to 900 tonnes, in an open building dock.

It is not expected that any new shipyards will be built or existing shipyards re-developed on a large scale in Western Europe during the current economic recession. A competitive position must be maintained therefore by European shipyards through effective use of resources and technology.

2. OBJECTIVES, FUNCTIONS AND INTERFACES OF PRODUCTION ENGINEERING

The application of Production Engineering techniques is certainly not new. When the industry was dependent on craft skills Production Engineering was an implicit function of the craftsman. So Production Engineering was learned and practised in the production area.

With a move away from the use of craft skills to operative skills, it is necessary to consider production engineering in a different way.

2.1 Objectives of Production Engineering

a) To assist production to achieve the targets and goals set out in the Corporate Plan.

b) To monitor production technology development in the industry.

c) To identify opportunities for cost reductions in production processes.

2.2 Functions of Production Engineering

a) Work process analysis and definition.

b) Value engineering.

c) Methods study.

d) Define equipment and tooling requirements.

e) Define technical information requirements for production work processes.

f) Liaison between production departments and service departments on production service requirements as in process specifications.

2.3 Production Engineering Interfaces

Production Engineering can be described as the process of selecting the most efficient methods for production workers having regard to the overall operational objectives, while working within agreed limits and constraints.

Process definition is a functional responsibility of Production Engineering. The definition of the shipbuilding process commences in the design office and is the commencement of the "Design for Production" concept. Production Engineering is therefore involved from this early stage and continues to develop and implement "Design for Production" concepts at all levels in all departments.

A detailed knowledge of production facilities is fundamental to Production Engineering. The physical layout of the facilities is a limitation within which Production Engineering takes place. It is also important that the limitations of skill available are considered and that agreed working practices are understood.

While the manufacturing, assembly and construction areas are considered within the sphere of Production Engineering, facilities maintenance and general services often create problems for production which could be avoided by effective integration into the work process definition. Production Engineering principles applied to staging, lighting, equipment maintenance stores, etc. can do much to improve the whole efficiency of the operation.

To effectively accomplish the objectives set out in paragraph 2.1 it will be necessary for Production Engineering to interface with the following:

- Technical Departments
- Industrial Relations
- Production Management
- Purchasing
- Sub-contractors
- Research and Development
- Quality Assurance
- Planning
- Production Control
- Quality Control
- Development Engineers (civil, mechanical, electrical)
- Production Semites Management (transport, staging, power etc.)

Management Information Systems (MIS) can be-of considerable-assistace to Production Engineering if structured to provide accurate feedback on production costs, manhours, resource utilisation and performance. MIS will then constantly and consistently provide a measure of effectiveness of the work processes, reducing the need for highly qualified Production Engineers to be employed on ‘special assignments’ requiring tedious hours of analytical searching for the facts.

3. PRODUCTION ENGINEERING TECHNIQUES

Work Study, incorporating Method Study and Work Measurement, as applied to other manufacturing industries, has met with limited success and in many cases total failure in the shipbuilding industry. This is thought to be due to the application of work study techniques to ill-defined tasks where traditional shipbuilding methods, largely composed of jobbing work, were existing. In some cases vast sums of money were spent on work measurement when the work to be measured was not defined. This was done on the premise that if one measured the work being done and analysed the results, one would identify the areas for improvement.

Such assumptions were invalid in traditional shipyards where the methods adopted were the responsibility of first level supenisors based on custom, practice and experience. Resource allocation to tasks was on a

random basis governed by the foreman’s knowledge of the skills existing in the men allocated to him. Much of the work in these circumstances was carried out in an unprotected environment, so job allocation and elapsed time for tasks was also a function of the climatic conditions.

Some European shipyards met with quite a high degree of success in implementing work study techniques. These were principally yards which had been re-developed and new shipyards where the concepts of manufacturing and construction were quite different from traditional practices and where tasks were carried out under cover in a controlled environment. The training and investment to mount such an exercise was expensive and required. a high. volume of sales to support the overhead cost which, when achieved, was certainly justified. The low levels of turnover currently being experienced cannot support high overhead costs and so many sophisticated work study applications have failed and fallen into disrepute.

Lessons have been learnt during this period of upsurge in work study which have pointed to the importance of Method Study in relation to Work Measurement. Many shipyards used their experience to concentrate on the critical activities which were identified during the period of Work Study and now find it sufficient to measure and monitor production at a relatively broad level of activity using a simple and cost effective approach. A change in product mix however could-make such assumptions quite invalid.

In pursuing Methods Study many analytical techniques may be employed to validate the work done, including data synthesis, analytical estimating, process charting, multiple activity charts, scale modelling, photography, network analysis, linear programming, simulation, etc., many of which are dependent upon good management information systems. There is no shortage of tools or techniques.

Value Engineering raises its head from time to time, is taken from the shelf, dusted off, used as a special exercise then put away again. This is misuse of a good technique which should be in constant use in all design departments.

4. DESIGN FOR PRODUCTION

Design for Production could be said to be a catch phrase which describes an implicit function of any good technical department. Hopefully this is true. But as technology, shipyard facilities, product design, materials

and the distribution of costs are continually changing and inter-acting with each other the significance of good design for production requires to be kept under review.

The significant impact which design for production can have on manufacturing and construction costs is often underrated. Similarly, the way in which construction methods are defined, although not specified, by the way in which assemblies are arranged on a drawing, is not always appreciated.

Time, people and facilities are valuable resources which must be used in a balanced way to achieve optimum efficiency. Such all round efficiency can only begin to be achieved if the design is well engineered and takes account of the resources available.

As technology continues to change, the task for technical departments is to keep abreast of these changes. commu-nication between departments directly involved in design and production should be easily developed but it is more difficult to take account of legislative developments. which may have a significant effect on working practices. Everything must be done during the stages of design to minimise production costs by recognizing the constraints and opportunities which exist in production departments. These interfaces have to be-tackled in a practical way. To-ignore them is to pass the problem down the line and in many cases to lose the opportunity of making a worth-while contribution to higher efficiency.

The scope of Design for Production will vary with the product and the facilities but the objective is quite singular - the reduction of production costs to a practical minimnun, whilst meeting conceptual design requirements and maintaining acceptable quality.

Design for Production is the basic requirement and has a most significant effect on production methods.

5. APPLICATION OF PRODUCTION ENGINEERING TECHNIQUES

Three areas of application are presented for discussion.

5.1 Block Breakdown

In any design, the choice of block breakdown is a fundamental decision which must allow use of the production facilities to maximum advantage and will determine the detailed structural arrange-ment of the design.

Structural arrangements should be developed such that the choice of block breakdown will give a

rapid rate of erection, fairing and welding of the ship's hull. This can be achieved by ensuring that the blocks are 'natural'.

Natural blocks have the following characteristics:

a) Manufacture is simple and economic.

b) Only one final assembly stage is required.

c) Their size and shape should provide a good basis for pre-erection outfitting.

d) Divisions of the hull may provide natural breaks between blocks.

e) Full use should be made of downhand assembly and welding activities for manufacture and construction.

f) Blocks should be self supporting after erection and involve the minimum amount of staging. Shoring and temporary supports should be eliminated as far as possible.

g) Lifting, turning (where necessary) and transportation should be able to be accomplished with the minimum of extra work and in a safe way.

Points for discussion:

- Construction philosophy.
- Facility constraints.
- Design features.
- Structural grouping.
- Ships systems.
- Risk.
- Access.
- Environment.
- Alignment methods.
- Pre-erection outfitting.
- Services.
- Materials.

5.2 Panel Line Design

Steel assembly work can be divided into five main categories:

a) Sub-assembly, which refers to the assembly of internal members such as webs, transverses, girders, floors and brackets.

b) Flat panel based unit assembly.
c) Curved and corrugated unit assembly.
d) 3D unit assembly.
e) Minor assemblies including outfit steelwork.

Category b) can benefit from the use of a purpose designed Panel Line. Such a panel line is often a mechanised assembly line with defined workstations. Plate positioning, alignment and welding could be automatic. Matrices and panel stiffeners may be mechanically positioned, faired and automatically welded. Features may include a purpose designed. turnover station, under line fairing, semi-automatic and automatic welding including robot welders.

Points for discussion include:

- Panel types and sizes.
- Capacity requirements.
- Workflow patterns.
- Physical constraints.
- Panel orientation.
- Line balance.
- Outfitting.
- Materials.
- Grillages.
- Operations manual.
- Transfer system.
- Technical information requirments.
- Quality control.
- Location.
- Manning levels.
- Environment.
- Services.
- Fairing aids.
- Cost benefit analysis.

5.3 Pipe Production

Next to steelwork, pipework manufacture and installation is the biggest labour cost in merchant ship construction. High productivity and low production costs for pipework have a significant effect on the vessel labour costs.

Purpose built pipe factories have been built to achieve low cost and high volume. Flow line, large batch and small batch production methods may be employed. Workstations may be set up for principal activities such as marking, cutting, bending, welding, facing, testing and cleaning: Pipe module assembly may also feature in the layout.

Points for discussion include:

- Pipe analysis.
- Materials.
- Connections.
- Quality specifications.
- Flow line vs batch sizes.
- Location.
- Stockholding policy.
- Material handling.
- Standards.
- Equipment and tooling.
- Material flow patterns.
- Amenities.
- Workstation definition.
- Operations manual.
- Pipe identification.
- Manning levels and working practices.

6. PRODUCTION ENGINEERING SKILLS

In examining the three preceding areas of application of production engineering techniques it will have been appreciated that the depth and breadth of knowledge required is very great. Technical expertise is certainly dominant. But technical competence is not enough, even if it is the passport to acceptability in the shipbuilding industry. A high level of skill is also required in Interpersonal Relationships and Leadership, with a task oriented approach as strong as the best production manager.

Points for discussion include:

- Source of production engineers.
- Skills and attributes of production engineers.
- Scope and applicability of production engineering in:

i) Merchant Ships.
ii) Warships.
iii) Specialist Ships.
iv) Offshore Structures.
v) Marine Engineering.

- Synergy in Production Engineering.

7. MANAGEMENT RESPONSIBILITY FOR PRODUCTION ENGINEERING

Executive directors are responsible for the development of their individual functions within the operational strategy of the Corporate Plan. Which discipline should have the responsibility for Production Engineering? Production, Technical, Industrial Relations or what?

In deciding the most effective position in the organisation for Production Engineering it may help to establish some of the implications.

Points for discussion:

- Relationships between production technology and the organisation.
- Levels of technology employed and production ambitions, their inter-action.
- Cost benefits of Production Engineering.
- Responsibility for work organisation.
- Responsibility for work methods.
- Responsibility for the social aspects of work patterns.
- Responsibility for work content in the contract.

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THE ROLE OF INDUSTRIAL ENGINEERING IN SHIPYARD PRODUCTION SERVICES

Contents

1. INTRODUCTION

In this session the role of the Industrial Engineering function as a service to Ship Production is being considered.

It is an extremely wide topic and various aspects have already been mentioned by previous speakers and, no doubt, will be mentioned again in future sessions.

This is not surprising in view of the essential role of management in making the best use of its resources. See Figure 1.

However, in order not to cover too much ground, which belongs to other sessions, it is the intention now to be mainly concerned with the resources of manpower - the labour force - and how they can best be utilised.

The importance of establishing a realistic and effective 'work pattern' for a shipyard labour force is often grossly under-estimated. This can be illustrated by taking two actual examples of similar European shipyards building similar vessels.

Shipyard 'A' achieves a 'productivity' of 20 man-hours. per ton of steel whereas Shipyard 'B' can only achieve 40 man-hours per ton, a case of double the output for the same labour input. Yet when these two yards are looked at in greater detail Shipyard 'A' is no more sophisticated in its equipment than Shipyard 'B' - it has no automated panel line, no single sided welding techniques, no plasma burning machines, no superior worker incentive scheme. The only difference is that Shipyard 'A' organises its work so very much better than Shipyard 'B'.

What are the things it is necessary to organise better ? Figure 2 identifies some of the 'High Hurdles' which management must clear to run an effective course for eac job.

Shipyard 'A' has a management which has identified its 'High Hurdles', has organised its work properly, has established the best methods and workplace layouts, etc. to ensure that work flows effectively, smoothly and without interruption. The workforce does not have to work any harder than in Shipyard 'B' - people just work without unnecessary interruption and so are able to maintain their natural rhythm.

This highlights the harvest which can be reaped by an effective and dedicated Industrial Engineering function.

2. THE NORMAL WORK PATTERN IN A SHIPYARD

The term 'Work Pattern' has already been used and a typical example is illustrated in Figure 3.

It is necessary to look into the reasons for these interruptions of 'Wait' and 'Search' on the daily routine. These are mostly skilled personnel and it is imperative their time is used effectively.

Is it the fault of management for failing to organise the work, or the fault of the workforce for being apathetic and failing to give a fair day's work for a fair day's pay ?

To answer these questions it is necessary to analyse how manufacturing time is built up.

Figure 4 indicates that any basic work content can have, superimposed upon it, four additions. Three of these are the responsibility of management and one, of the workforce.

It is useful to look more closely into the activities, or lack of them, which make up these additions as this-will indicate the scope of development programmed which can be undertaken by the Industrial Engineering function to eliminate unnecessary work and ineffective time.

Figure 5 identifies how the basic work content is inflated by either:

- defects in design-or specification

or:

- inefficient methods of manufacture and specification

The former will concentrate the Industrial Engineer's attention onto the problems of the Design & Drawing Offices, Purchasing and Quality Assurance departments while the latter will be concerned with Production Engineering, Plant Engineering and Training departments.

From Figure 6 we can identify some of the Development Programmed which can be undertaken by the Industrial Engineer to eliminate or reduce excessive work content.

These are summarised in Table 1 below.

TABLE 1

Reason for excessive Work Content	Development or Improvement Programme
A. Design Defects.	1. Product Development 2. Specialisation and Standardisation 3. Market, Consumer and Product Research
B. Inefficient Methods	1. Process Planning 2. Method Study 3. Operator Training

Considering now the non-working, time-wasting elements it will be seen from Figure 7 that the biggest scope for improvement lies with management.

Nine headings fall into the category of management responsibility whereas only three are within control of the workforce.

It is important not to forget a fourth heading which embraces both - worker motivation. This does not only relate to money, but more especially to the general working environmental - in other words 'job satisfacti

If a worker is aware of managements effectiveness in eliminating and reducing non-productive time then, quit automatically and without incentive, he will apply hims to his work and be more productive.

From Figure 8 we can identify some of the Development Programmed available to the Industrial Engineer in redu non-productive time. These are summarised in Table 2 b

TABLE 2

Responsibility for Ineffective Time	Development & Improvement Programmes
C. Management	1. Marketing & Specialisation 2. Standardisation 3. Product Development 4. Production Control. 5. Material Control 6. Maintenance 7. Environmental 8. Safety
D. Workers	1. Motivation 2. Training 3. Safety

All the techniques, development and improvement programmed referred to above have one and the same objective - to improve Productivity.

3. WHAT IS PRODUCTIVITY?

The simplest and most meaningful answer to this is given in Figure 9.

If it is remembered that in this session, concentration is on the labour force and manpower resources then 'Output' may be defined in many ways, e.g. :

- Net tons of steel
  (Burnt, Fabricated, Erected, Faired, Welded, etc.)
- Number or weight of pipes
  (Type, Formed, Bent, Fabricated, Welded, etc.)
- Number of square metres processed
  (Accommodation bulkheads erected, area shotblasted, area painted, etc.)
- Number of Standard Hours produced
- Etc.

"Input" may be defined as the number of man-hours required to produce the 'Output'. Different interpretations are available, such as:

- Direct worker man-hours
- Direct and inditect worker man-hours
- Total Production department man-hours (including first line supervision)

Obviously the first of these options will give the best result, as far as a measure of Productivity is concerned, and it is therefore extremely important when comparing statistics between yards to ensure that like is being compared with like.

Improvements in Productivity - based on our previous formula - can be achieved by increasing output with the same input, maintaining output with a reduced input or a combination of both.

4. THE MAJ0R FACTORS WHICH INFLUENCE PRODUCTIVITY

It will be recalled that in the previous section, a detailec breakdown was made of the additions to basic work content and ineffective time.

In order to assess these in practical and quantitative terms it is possible to group them into three main influencing factors. These are:

a) Workers Performance (See Figure 10):This is the worker's contribution to Productivity and relates to his/her/thei achievement against set targets.

This is essentially in two parts: Firstly, the rate of the worker when actually working and, secondly, the ineffective time which is within his/her control.

With regard to the former, there is normally little difference in the rate when actually working. Each one has his own pace which it is difficult to change. It is the latter part, motivation of the worker to eliminate ineffective time within his control, where the biggest improvements in Productivity can be achieved.

b) Workforce Utilisation (See Figure 11): This is part of management's contribution to Productivity and relates to their success in eliminating ineffective time and providing a smooth and largely uninterrupted work patterr

c) Method Level (See Figure 12): This is the other part of management's contribution and relates to the layout equipment, tools and working methods which they provide and specify to execute the work in the best possible manner. .

5. THE COMPOUNDING EFFECTS OF THESE FACTORS IN A TOTAL CONCEPT

If work output is considered to be the volume of a cube it is possible to relate each of the factors above to a particular axis of the cube. (See Figure 13).

'Performance' can be considered as the X-axis and any improvement effected by the motivation of the worker will increase the volume of the cube along this axis as depicted in Figure 14.

'Utilisation' can be considered as the Y-axis and any improvement effected by better managerial skills will compound the effect of the previous 'Performance' increase along the Y-axis as depicted in Figure 15.

Finally 'Method Level' may be taken as the Z-axis and any improvement effected by better technology will compound the effects of both the 'Performance' and 'Utilisation' increases along the Z-axis as depicted in Figure 16.

Figure 17 illustrates the total effect and it can be demonstrated that the most modest improvements in each of the three major factors will have a considerable overall effect.

Figure 18 shows that improvements of 15% in 'Method Level' and 'Utilisation' and 20% in 'Performance will give a compounded effecton total Productivity Improvement of nearly 60%.

In the light of these figures it is not so surprising that the first example of Shipyard 'A' and Shipyard 'B' showed such results.

6. WORK MEASUREMENT

It is important to consider the tools available to the Industrial Engineer to enable hint to plan, execute and quantify his Productivity Improvement work. There is no doubt that the most important of these is Work Measurement.

"When you cannot measure it in numbers your knowledge is of a meagre and unsatisfactoory kind".

So said Lord Kelvin, President of the Royal Society from 1890 to 1895.

Unfortunately, in many sectors of the manufacturing industry today, including shipbuilding, Work Measurement is regarded by both management and unions as something a little unpleasant, but which is necessary to run a worker incentive scheme.

Those shipyards which are efficient, and produce Productivity indices like Shipyard 'A', have recognised that Work Measurement is an all-embracing Management tool which can assist them across the whole spectrum of their operation - Product Development, Product Costing, Manning Levels, Production Planning and Control, Facility Layout, Material Flow, etc. and maybe at the end, to skim off the cream with an incentive payment plan.

Due to the complexity, size and varied nature of shipbuilding work there has always been a fear in the industry that Work Measurement is not for them - they are a special case.

Fortunately, in line with other technological innovations, Work Measurement techniques have been improved and greatly simplified since the birth of Predetermined Motion Time Systems some 40 years ago. See Figure 19.

Whereas such systems, of which methods Time Measurement is internationally accepted as the best, were limited in their scope due to the wealth of detailed analysis required, derivation of the first MTM system have progressively simplified their use so that, for the last decade, all the work of a shipyard can be readily measured in an effective and economical manner.

One such system which is available, based on original MTM data, is called MOST - an acronym for Maynard Operation Sequence Technique.

This technique, already used in shipyards, has been referred to by a previous speaker but, in tke context of Industrial Engineering, is worthy of closer scrutiny.

The design criterion for MOST was that it should enable the measurement of two minutes of work to be carried out to a consistency of ± 5%. It was thus intendedcto be of comparabl accuracy with MTM-2 and considerably better in this respect than Time Study.

Statistical theory shows that to achieve this accuracy, considerable tolerance is possible in the measurement of the individual movements of an operator which go to make up two minutes of work. It is not necessary therefore to break these movements down into very small elements and to have different values for small increments of distance and weights of objects moved. In fact, manual work can be subdivided into only seven basic activities which are represented by the following code letters.

CODE	DESCRIPTION	EXAMPLES
A	Movement in a horizontal plane, freely through space	Reaching for an object, walking
B	Vertical body movements	Climbing on a platform, bending to the floor
M	Movement of an object which is restricted in at least one plane	Moving a lever, drawing a line with a rule
G	Gaining control of an object	Grasping an object
P	Positioning an object	Placing an object on a table, starting a nut on a bolt
I	Alignments	Setting a dial, aligning a rule to a mark
X	Process times	Time for crane movement, time for cooling

Moreover, computer analysis of Maynard's extensive library of MTM studies showed that these activities normally occur in set sequences. Three sequences were identified to cover all manual work.

A B G A B P A	General Move Sequence
A B G M X I A	Controlled Move Sequence
A B G A B P ( ) A B P A	Tool Use Sequence

Some means of classifying and quantifying the activities (A,B,G etc.) according to their extent and degree of difficulty was needed and this was done by placing an index number as a suffix to the letter, thus - $A_6\ B_6\ G_1 A_1 B_0 P_3\ A_0$

In this example the letters and indices indicate:

A_6	Walk 3 to 4 steps
A_6	Walk 3 to 4 steps
B_6	Bend and arise
G_1	Grasp one light object
A_1	Move the object, to a point within reach
B_0	No vertical body movement needed
P_3	Position the object with a small adjustment
A_0	No return move

The indices are taken in fact from a data table shown belo

ABGABPA GENERAL MOVE

INDEX	A ACTION DISTANCE	B BODY MOTION	G GAIN CONTROL	P PLACE	INDEX
0	≤ 2 IN ≤ 5 CM			TOSS	0
1	WITHIN REACH		LIGHT OBJECT LIGHT OBJECTS SIMO	LAY ASIDE LOOSE	1
3	1 - 2 STEPS	BEND AND ARISE 50% OCC	HEAVY OBJECT BLIND/OBSTRUCTED DISENGAGE INTERLOCKED COLLECT	ADJUSTMENTS LIGHT PRESSURE DOUBLE	3
6	3 - 4 STEPS	BEND AND ARISE		CARE/PRECISION HEAVY PRESSURE BLIND/OBSTRUCTED INTERMEDIATE MOVES	6
10	5 - 7 STEPS	SIT/ STAND			10
16	8 - 10 STEPS	THROUGH DOOR ON/OFF PLATFORM			16

The card is a series of horizontal time ranges for each activity. For each activity, the square corresponding to each time slot, there is a key-word description of the extent of the activity appropriate to that time range e.g., horizontal movements (A) within reach correspond to the time slot with the index 1; a vertical body movement (B) consisting of a bend and arise, corresponds with time slot index 6, and so forth.

The indices are really times in multiples of 10 TMUs (1 TMU = 0.00001 hrs, or 0.036 seconds). Therefore an index of 3 represents 30 TMUs.

The standard time for a sequence is obtained by adding the indices and multiplying by 10.

In the previous example:

$A_6\ B_6\ G_1\ A_1\ B_0\ P_3\ A_0$

$6 + 6 + 1 + 1 + 0 + 3 + 0 = 17$

the standard time is 17 x 10 = 170 TMUs (6.12 seconds).

The data card was constructed from statistical theory so. that each time slot was of such a width that its mid-point was within the tolerance needed to measure the activity covered by it, i.e. the time slot denoted by the index 3 spans from 17 to 42 TMUs which means that all activities falling within this range can be given the value of 30 TMUs and this will be sufficiently accurate to measure a piece of work covering 2 minutes, provided all other activities going to make up the 2 minute parcel are also measured to the appropriate accuracy.

It will be seen, for example, that both 1 and 2 walking steps fall within the A_3 slot. This, and all other reference activities on the data card, was established from an MTM analysis. MOST is therefore a very simple and rapid application technique for MTM, and as such is completely compatible with other standards built from MTM. A sample MOST analysis is shown in Figure 20.

The MOST system can be learned in one week and is easy to apply. A comparison of its speed of application against other MTM systems and Time Study is shown in the following table.

Technique	Ratio Study Time: Standard Time	Pages of Analysis
MOST	5 - 10	1
MTM-1	300 - 500	16
MTM-2	100	10
MTM-3	30 - 50	8
Time Study	30	4

As regards accuracy, in practice MOST has shown up, in comparisons with other systems, better than intended in the theoretical design criteria. This is because, due to inherent simplicity, there are far fewer analyst errors with MOST, and consequently it has given results, down to cycle times of a few seconds, comparable with those obtained using MT14-l.

Such a system of Work Measurement can therefore be used to produce Work Sheets which may be unique to a particular product in any particular shipyard and which can be conveniently and rapidly used to establish Standard Time for jobs.

A previous speaker has already referred to Operation Time Calculation sheets; Figures 21, 22, 23, 24 and 25 illustrate examples of such sheets covering Plate Preparation, Panel Assembly, Weldment Assembly and Hull Pipework Outfitting work.

7. ORGANIZING THE WORK

Now that Work Measurement has been established as a major Industrial Engineering Tool it is necessary to consider how a department should be organised to cover all the aspects which have been mentioned previously.

Figure 26 shows a typical organigram of a Shipyard Production Semites Division.

Looking at the four sub-headings under Industrial Engineering, each function has a specific role to play.

Project Engineers

Their role is to look to the future and' develop Product Design to best suit Productions needs. They must obviously work closely with Design and Drawing Office departments. Typical projects will be:

0 Unit Breakdowns

o Block Weldments

o Standardisation of Minor Parts

o Advanced Outfitting

o Value Analysis

o etc.

- Production Engineers

Their role is with the present i.e. The documentation of layouts, process instructions, manual methods, tools and equipment required etc. Typical outputs will be:

o Production Flow Diagrams

o Technical Method Documents

O Manual Method Documents

o Process Instruction Documents

o etc.

- Work Analysts

These are the Work Measurement technician, Data Bank administrators, etc. Typical jobs are:

o Data Bank Administration

o Operation Time Calculation Sheets

0 Process Time Calculations

o Sampling for Allowances

o Analysis of Complete Jobs

o Compilation of Management Control Information

0 etc.

- Work Preparatory

These work closely with first line supervision and productio planning and control to ensure that all necessary document tation, equipment and materials are available for work scheduling in the immediate future. Their contribution

to the Utilisation factor is considerable. Their output will include:

- o Work Control Cards
- 0 Material Requisitions
- 0 Transport Requisitions
- 0 Safety Documentation
- 0 etc.

8. MANAGEMENT CONTROL INFORMATION

Having set up our Industrial Engineering organisation it is important that its members do not operate in an ‘ivory tower’ situation. It is a foregone conclusion that they must co-operate with all related departments in their approach to work, but it is also vital that they disseminat information as to what has happened e.g.:

- how did the shipyard perform against target ?
  what corrective action if any, is required ?
- how should it be achieved ?

This is a continuous monitoring progress, a close loop system as depicted in Figure 27 - so what form should these controls take ?

At the beginning of this session mention was made of traditional statistics such as man-hours per ton of steel, etc.

These are adequate for general use and discussion but how, for instance, can management compare the effectiveness of its fabrication department to that of its joinery department

The answer is a standardised measure of effectiveness - the ‘Standard Hour’- which we have already mentioned in Section 3.

This becomes possible because of the use which can be ma of PMTS work measurement. All work is measured based on the original fundamental manual motions, whether one talks of steelwork, joinery, pipework, painting etc.

In this respect it is possible to produce comparable manage- ment control information based on the factors we have already discussed.

- Departmental Work Performance

$$= \frac{\text{Total Standard Hours completed this week}}{\text{Total Actual Hours Taken}} \times 100$$

- Departmental Utilisation

$$= \frac{\text{Total Attendance Hours - Stoppages}}{\text{Total Attendance Hours}} \times 100$$

- Departmental Efficiency

$$= \frac{\text{Total Standard Hours completed this week}}{\text{Total Attendance Hours}} \times 100$$

- Departmental Cost .

= Cost per Standard Hour

$$= \frac{\text{Payroll}}{\text{Total Number of Standard Hours completed}}$$

9. CONCLUSION

The entire Industrial Engineering function is an overhead; and therefore vulnerable.

A shipyard will happily say - we need another fifty-welders but, sorry, we cannot afford three more Industrial Engineers It is the difference between 'productives' and 'non-produtiiv

Let us get things in their proper perspective; let us analyse the harvest that each function, each individual can reap.

It is only necessary to look at Japan, which is generally accepted to be one of the most productive manufacturing nations. In Japanese shipbuilding, Production Support Services are over double in size to those of their European counterparts.

Let us recognise the service which Industrial Engineering can provide to Shipyard Production and make it happen.

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2. INTRODUCTION TO WORK STUDY — The International Labour Office Geneva. 1967

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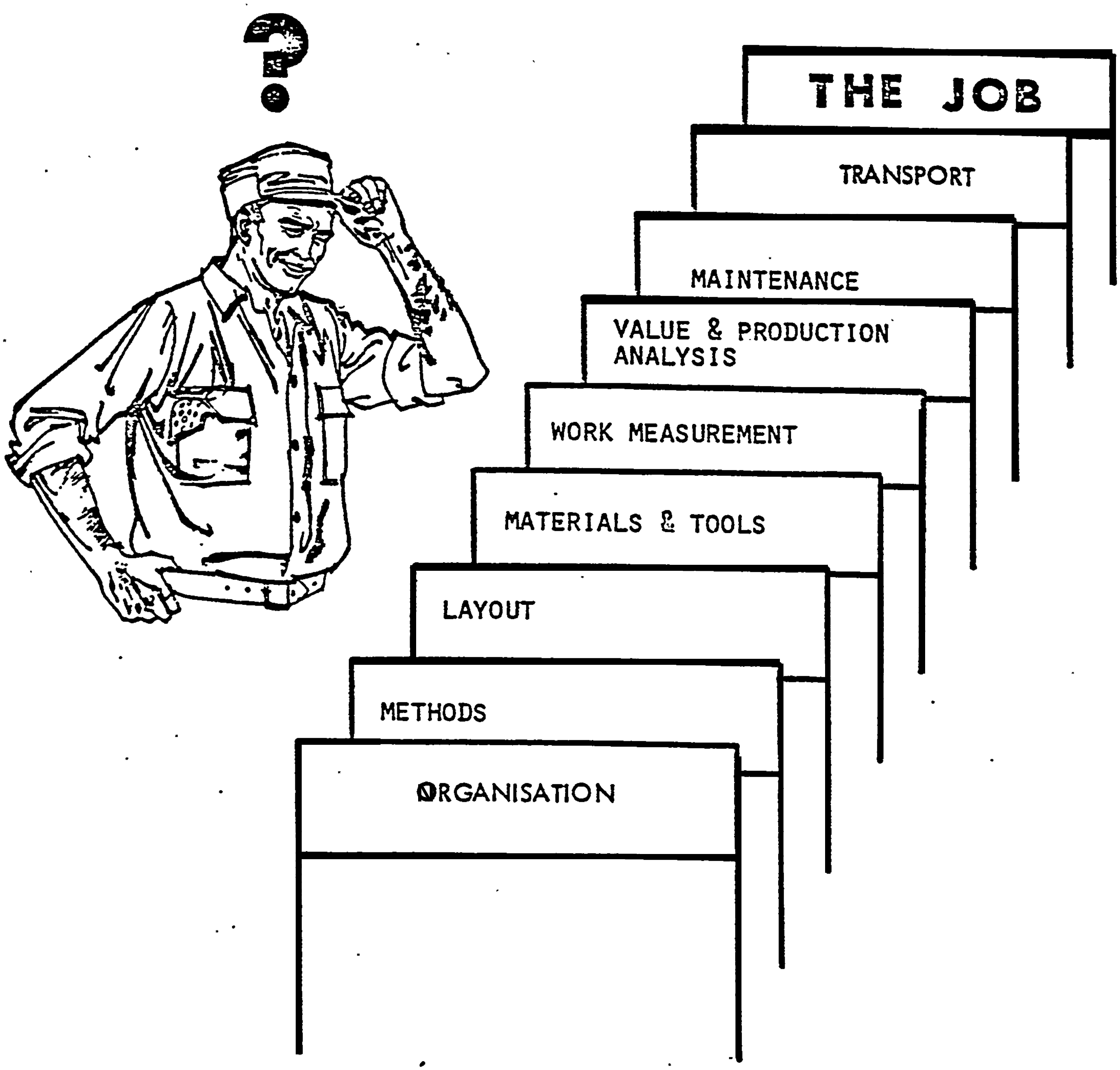
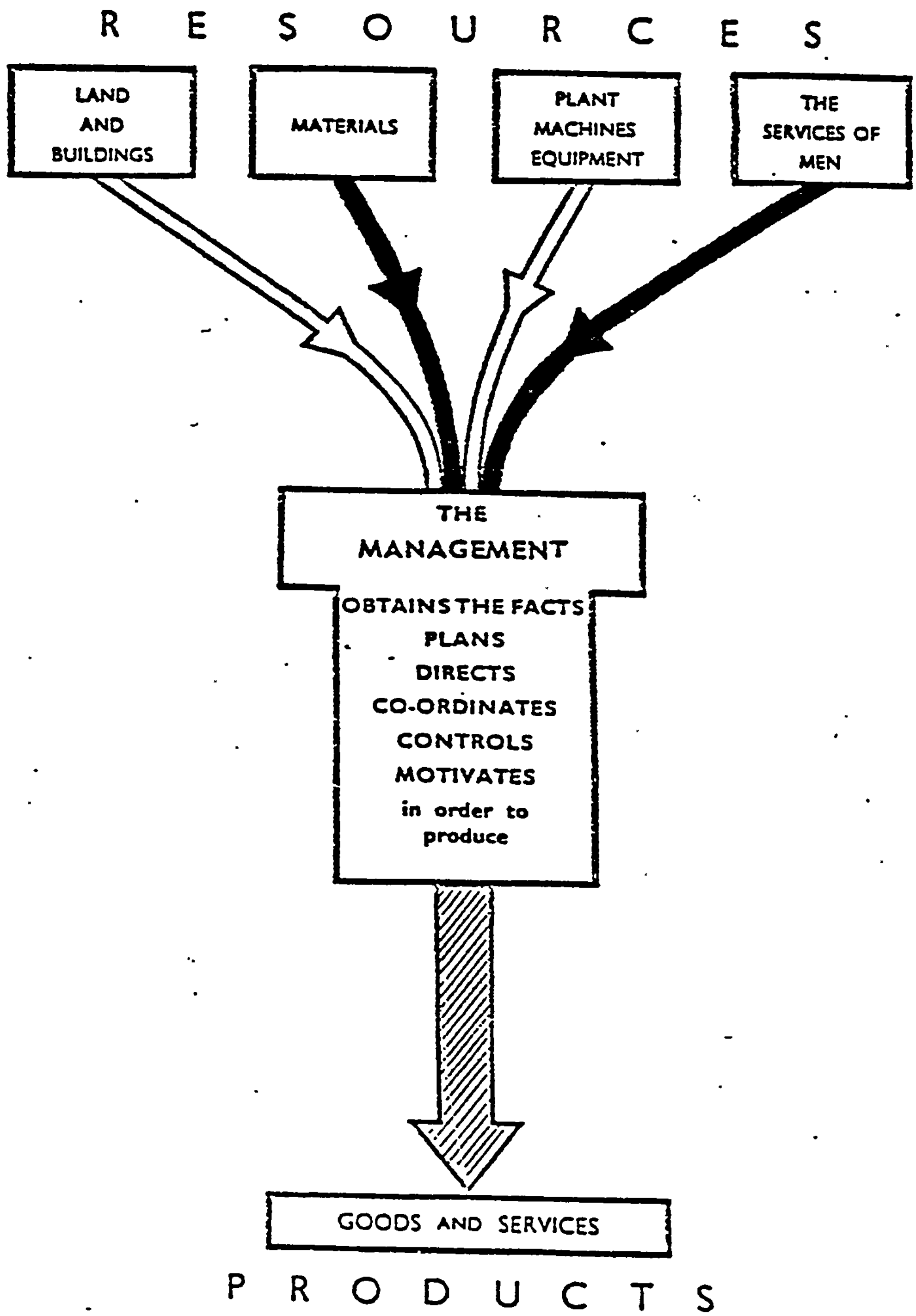
FIGURE 2.

HIGH **HURDLES**



THE ROLE OF THE MANAGEMENT IN CO-ORDINATING THE RESOURCES OF AN ENTERPRISE



TYPICAL WORK PATTERN

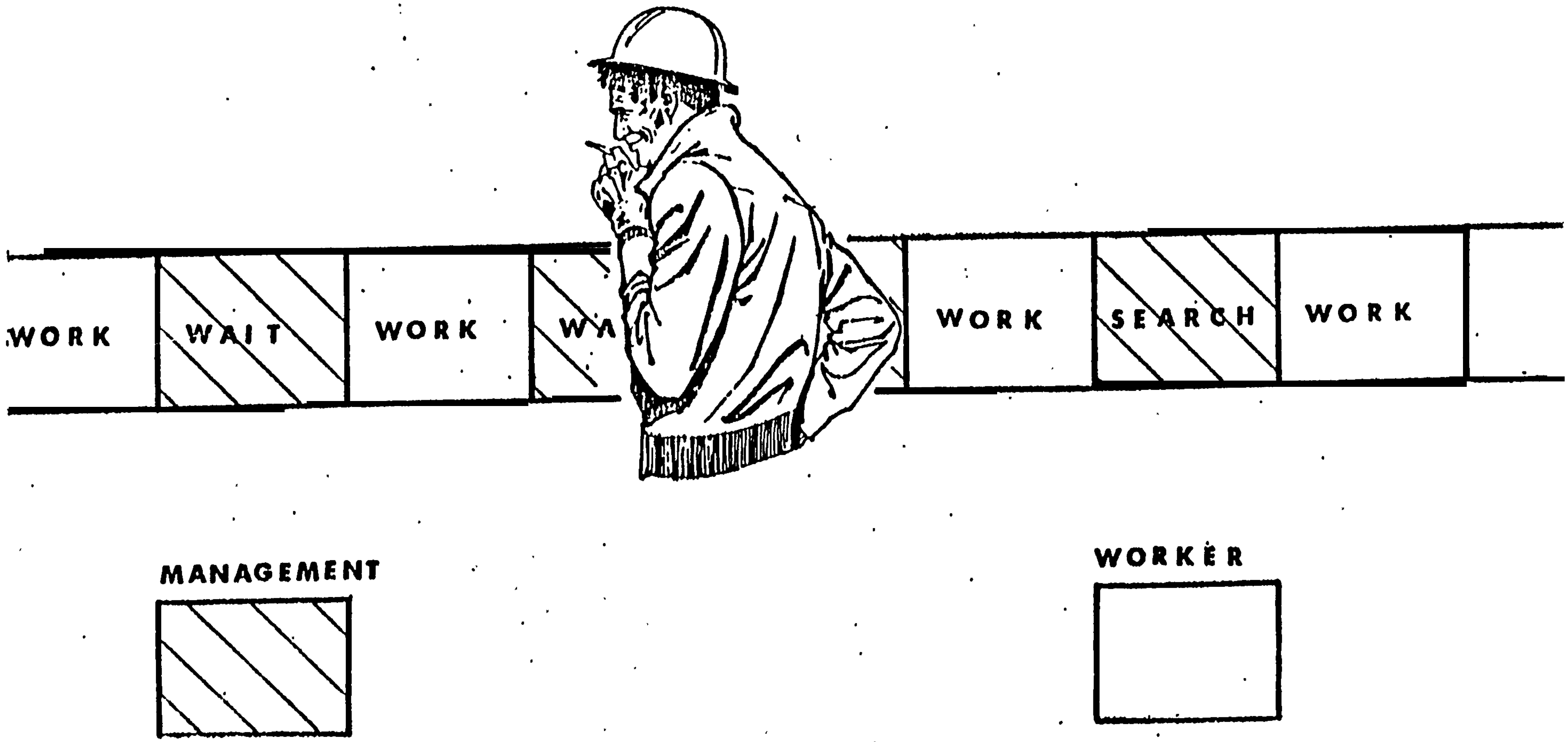
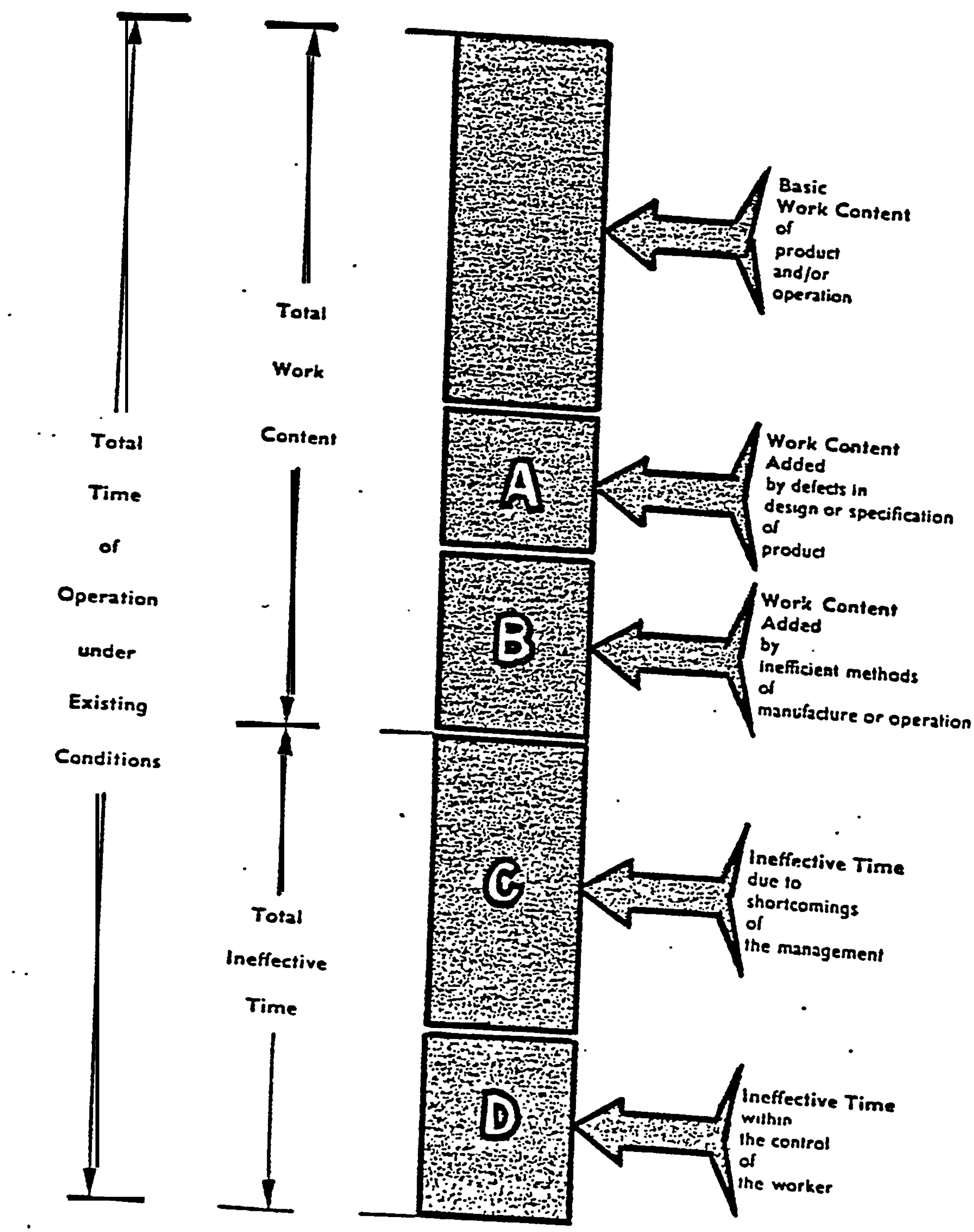
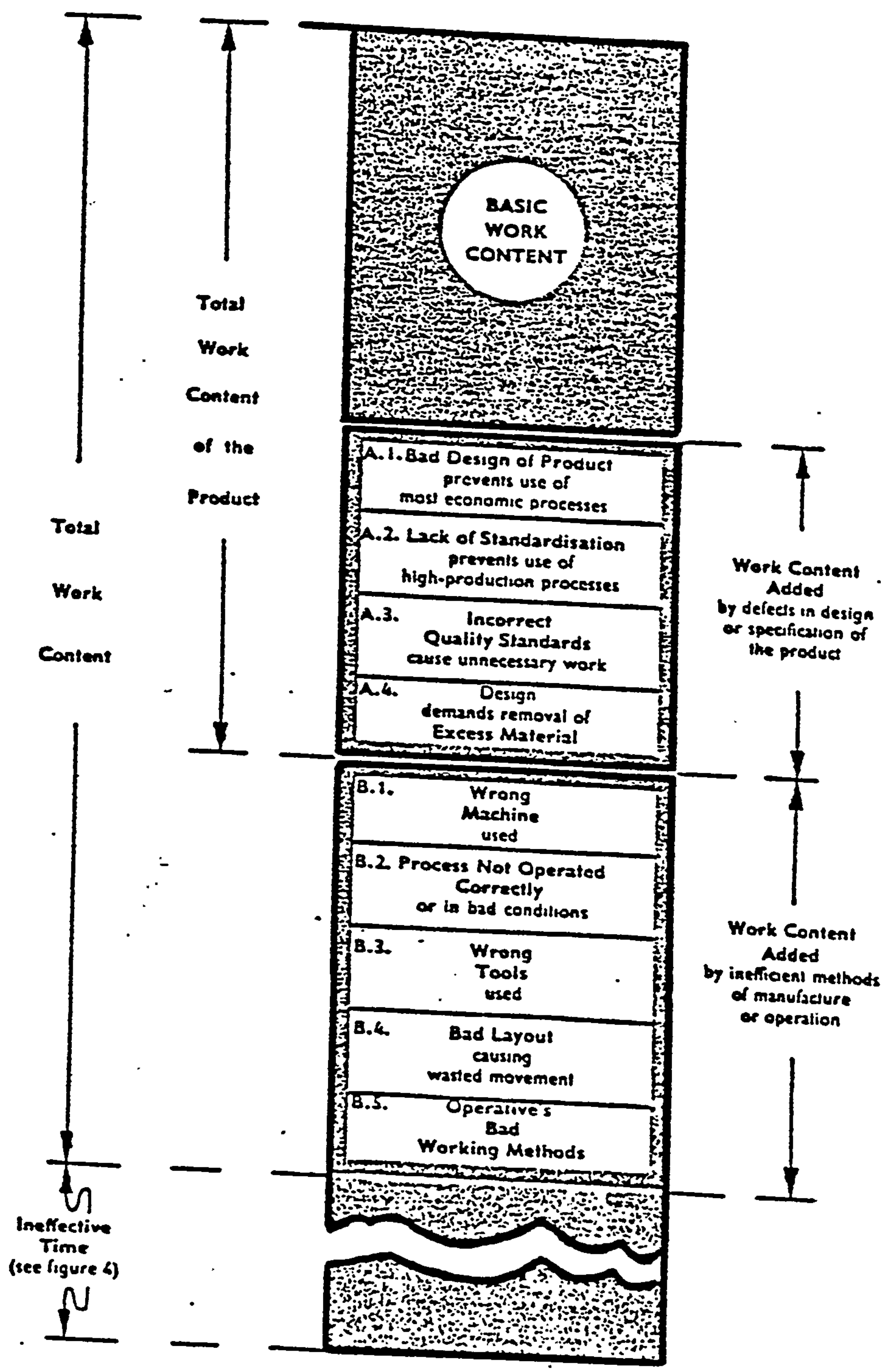


FIGURE 4.

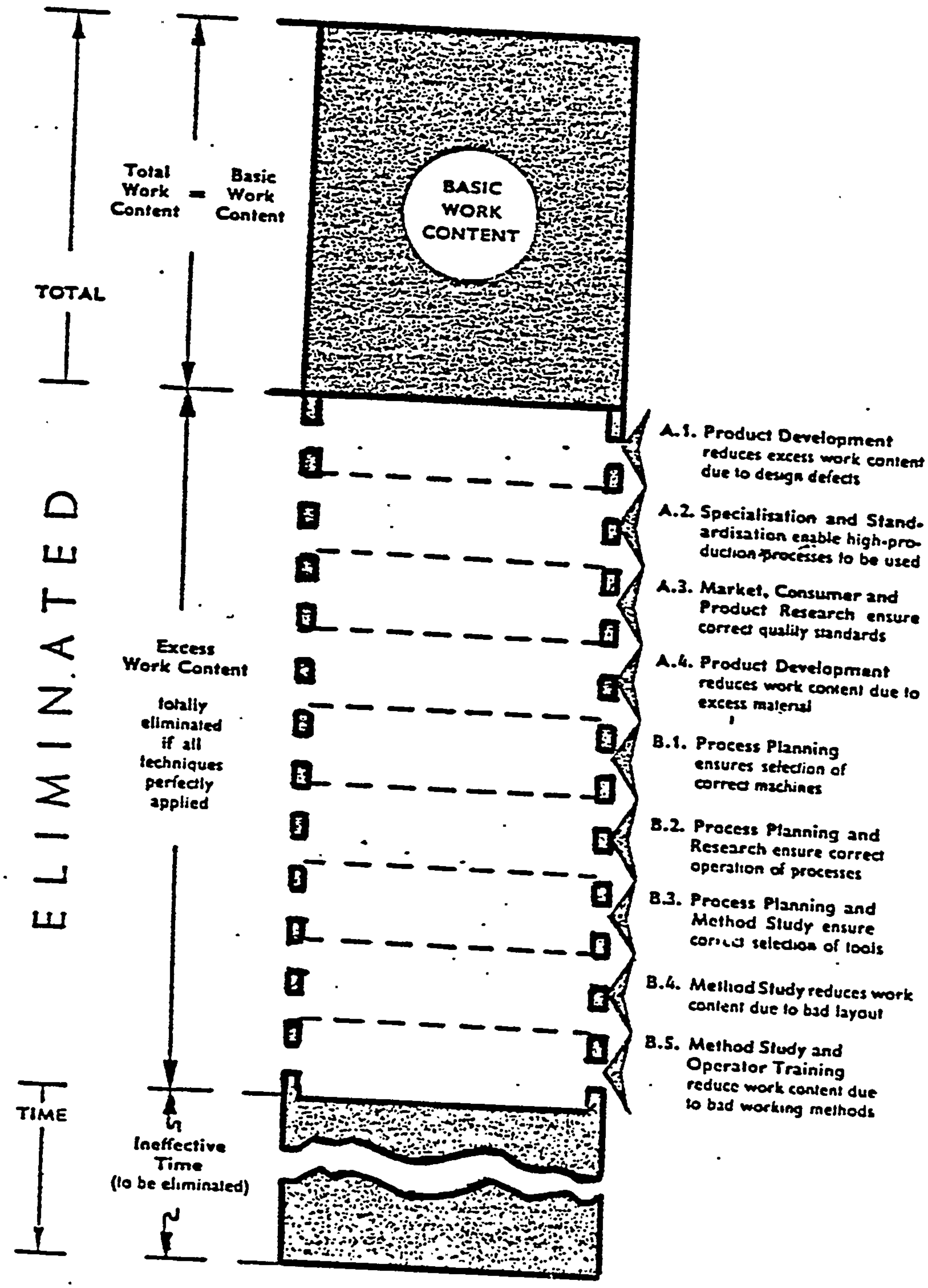
HOW MANUFACTURING TIME IS MADE UP



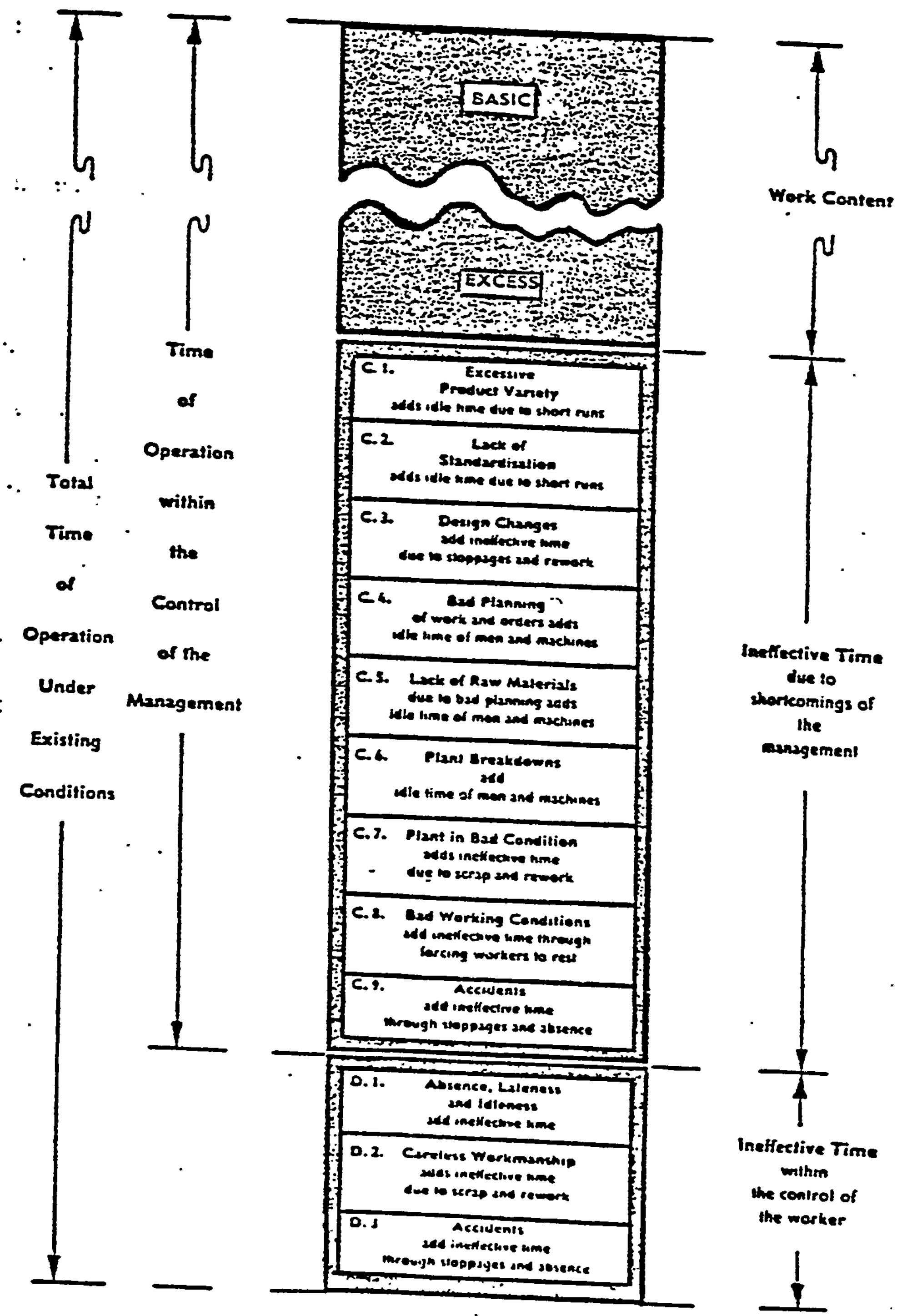
THE WORK CONTENT DUE TO THE PRODUCT AND PROCESSES



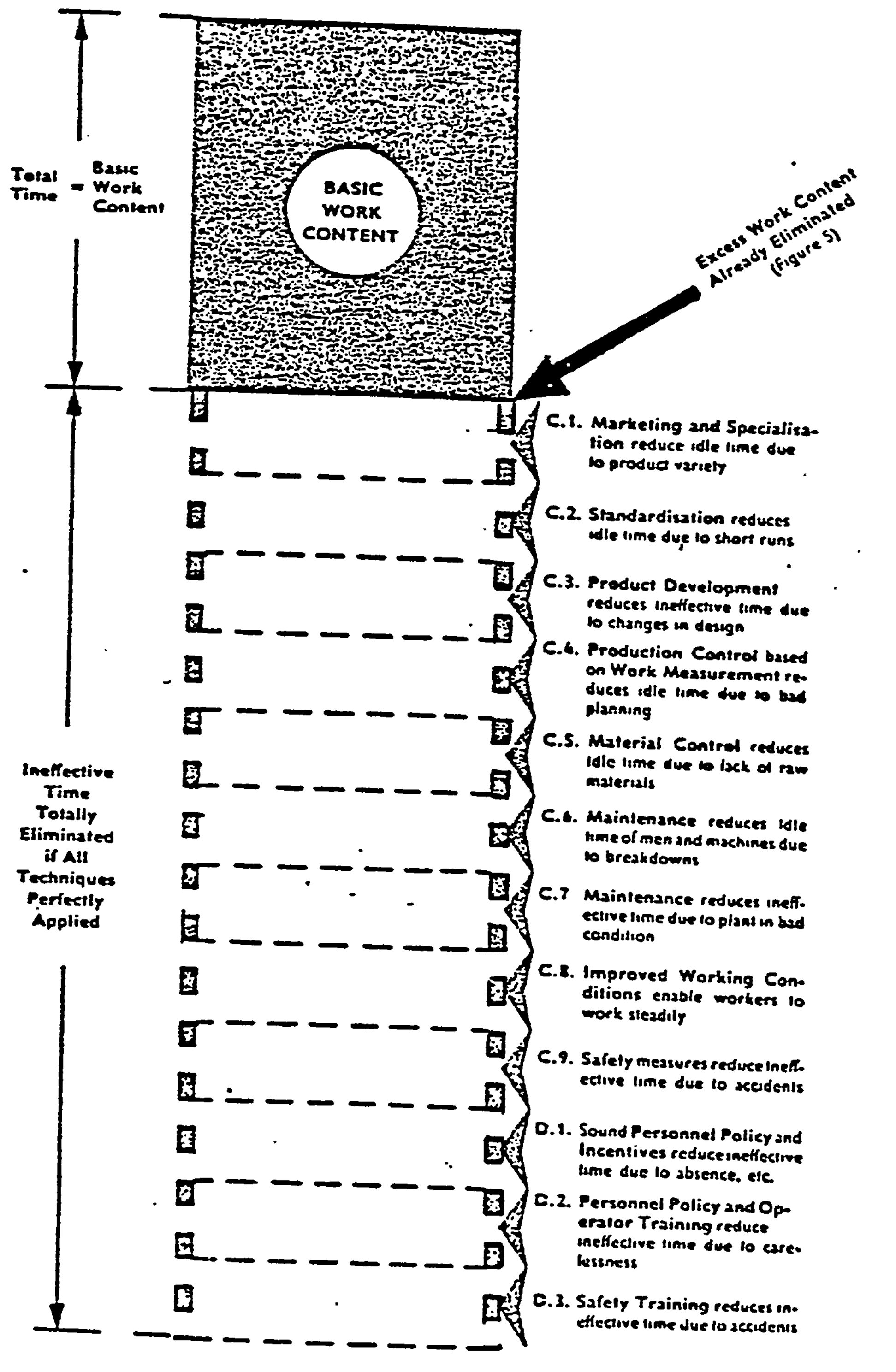
HOW MANAGEMENT TECHNIQUES CAN REDUCE EXCESS WORK CONTENT



INEFFECTIVE TIME DUE TO SHORTCOMINGS ON THE PART OF MANAGEMENT AND WORKERS



HOW MANAGEMENT TECHNIQUES CAN REDUCE INEFFECTIVE TIME



Productivity

$$= \frac{\text{OUTPUT}}{\text{INPUT}}$$

DEFINITION:

W O R K E R   P E R F O R M A N C E

THE RATIO OF THE TARGET OR MEASURED WORK CONTENT STANDARD MANHOURS TO THE ACTUAL MANHOURS TAKEN.

E.G. $\dfrac{\textbf{80 STANDARDS MANHOURS}}{\text{100 } \textbf{ACTUAL MANHOURS TAKEN}} \times 100$

=80 PER FORMANCE

DEFINITION:

WORRKER UTILISATION

THE PERCENTAGE RATIO OF THE DIFFERENCE BETWEEN ATTENDANCE MANHOURS AND STOPPAGE MANHOURS TO THE ATTENDANCE MANHOURS.

$$\text{E.G. } \frac{200 \text{ ATTENDANCE MANHOURS} - 40 \text{ STOPPAGE MANHOURS}}{200 \text{ ATTENDANCE MANHOURS}} \times 100$$

= 80% UTILISATTION

DEFINITION:

METHOD LEVEL

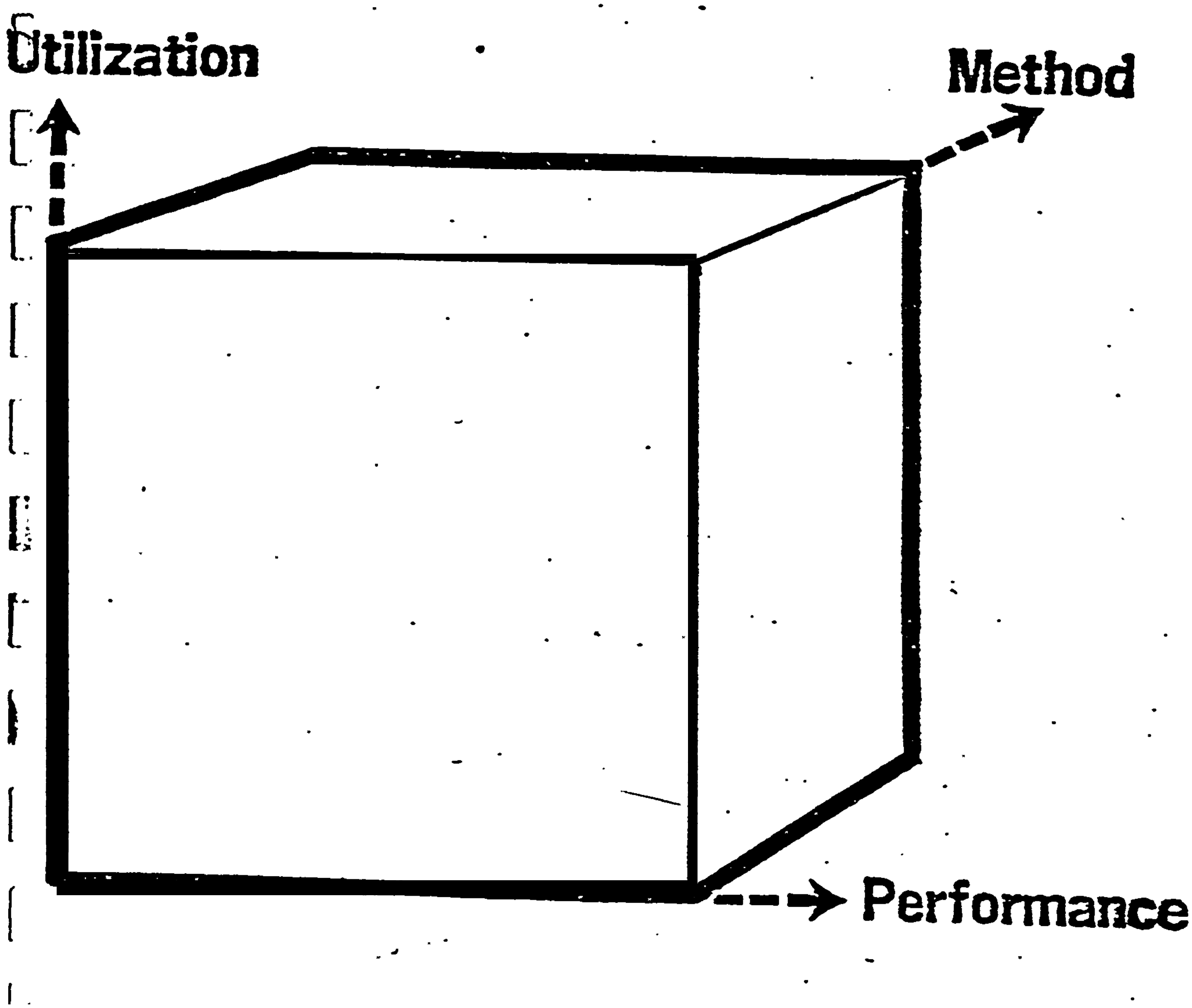
THE PERCENTAGE RATIO OF THE PROJECTED MEASURED, OR STANDARD MANHOURS TO PERFORM THE JOB USING AN IMPROVED METHOD TO THE MEASURED, OR STANDARD MANHOURS USING THE EXISTING METHOD,

E.G.

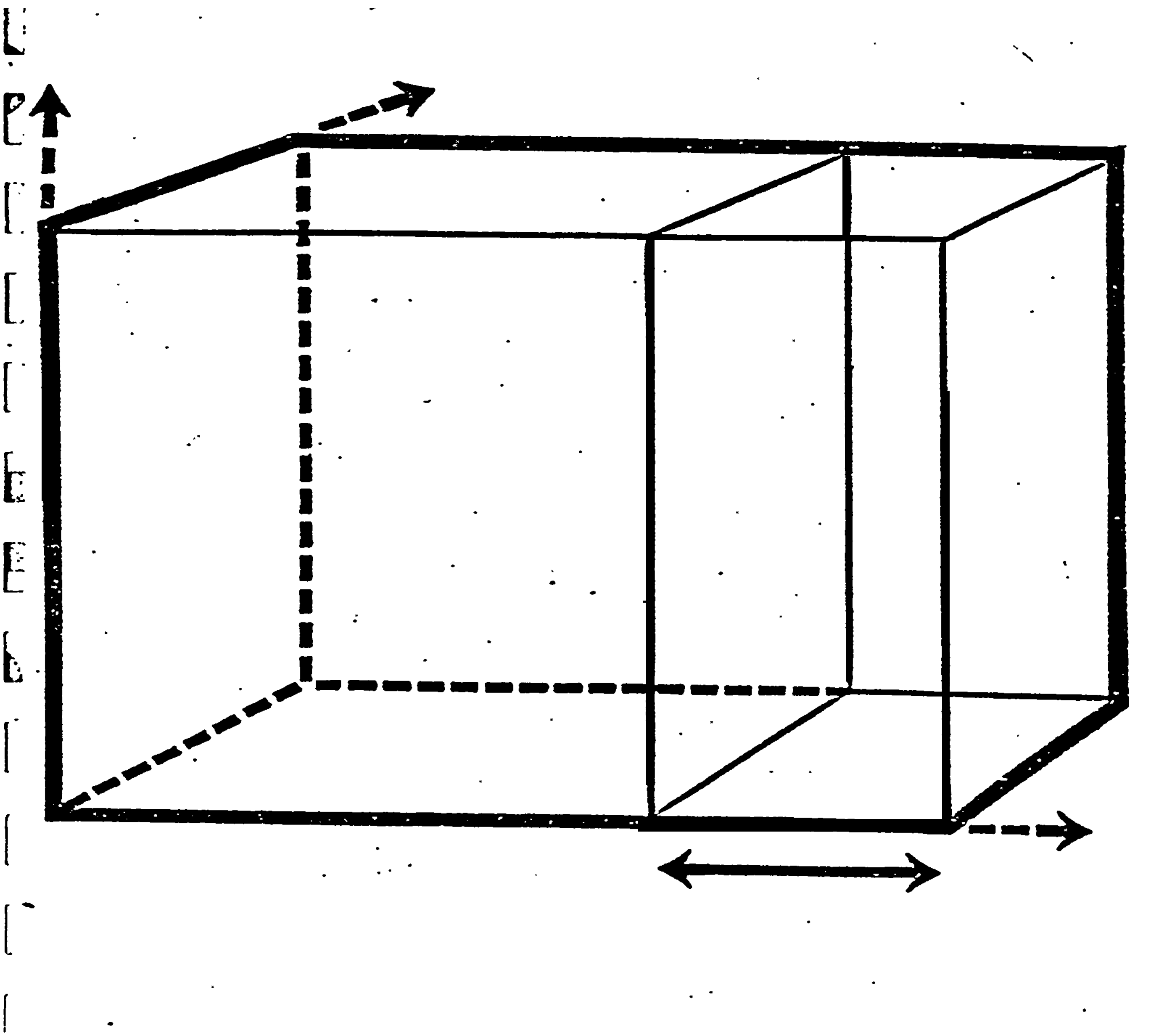
$$\frac{\text{80 STANDARD MANHOURS FOR PROJECTED METHOD}}{\text{100 STANDARD MANHOURS FOR EXISTING METHOD}} \times 100$$

= 80% METHOD LEVEL

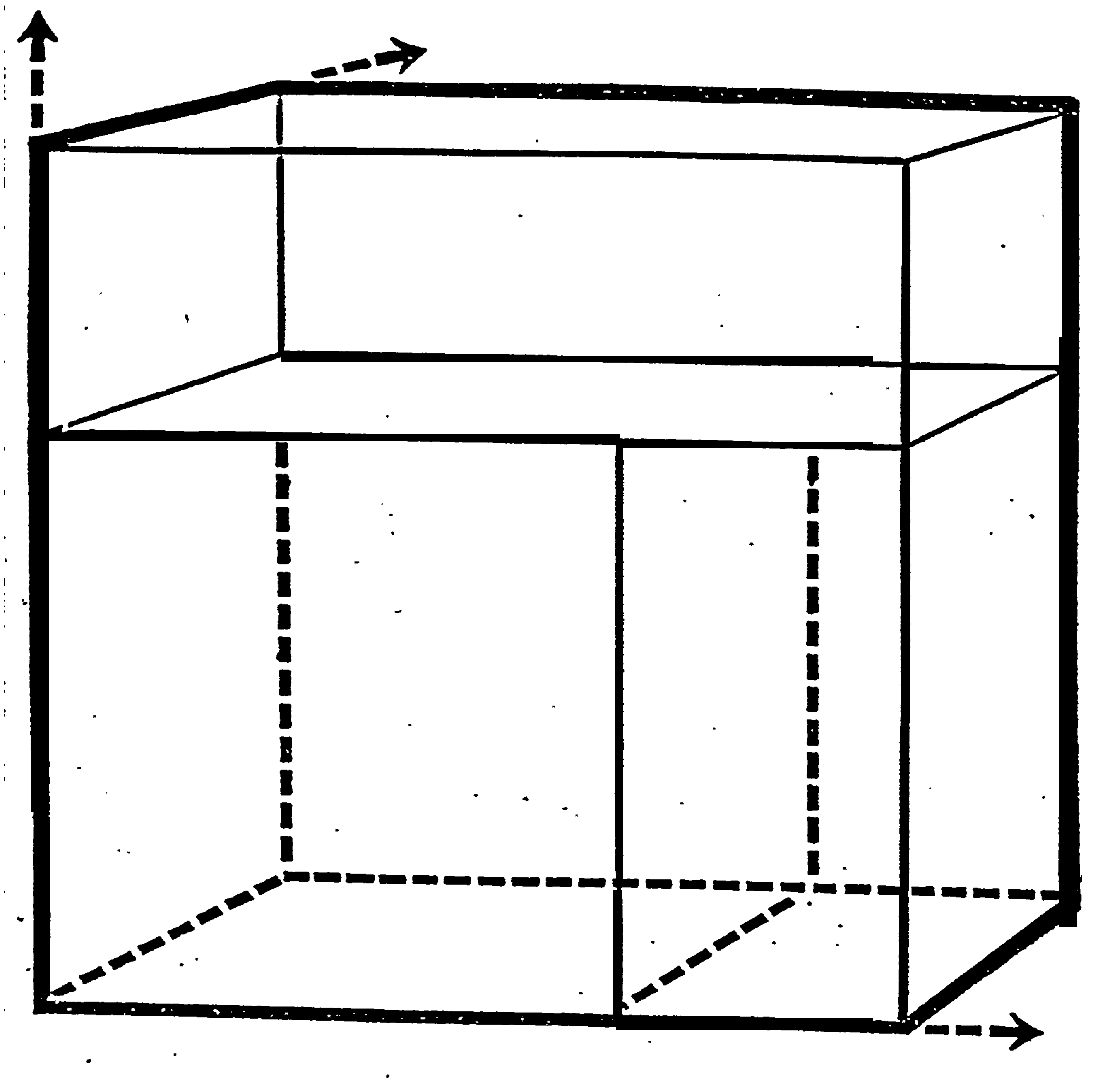
Productivity Factors



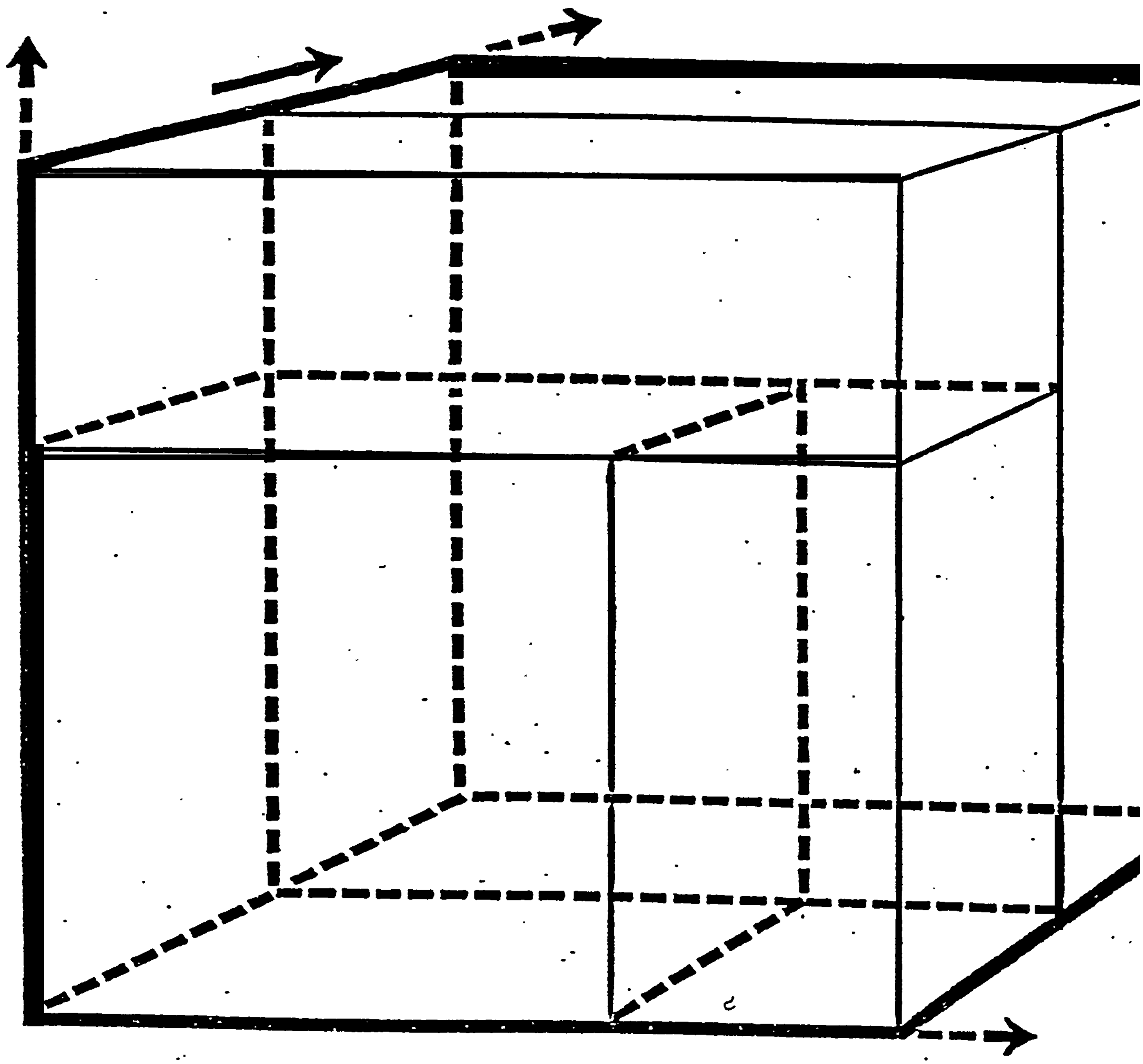
Performance Increase



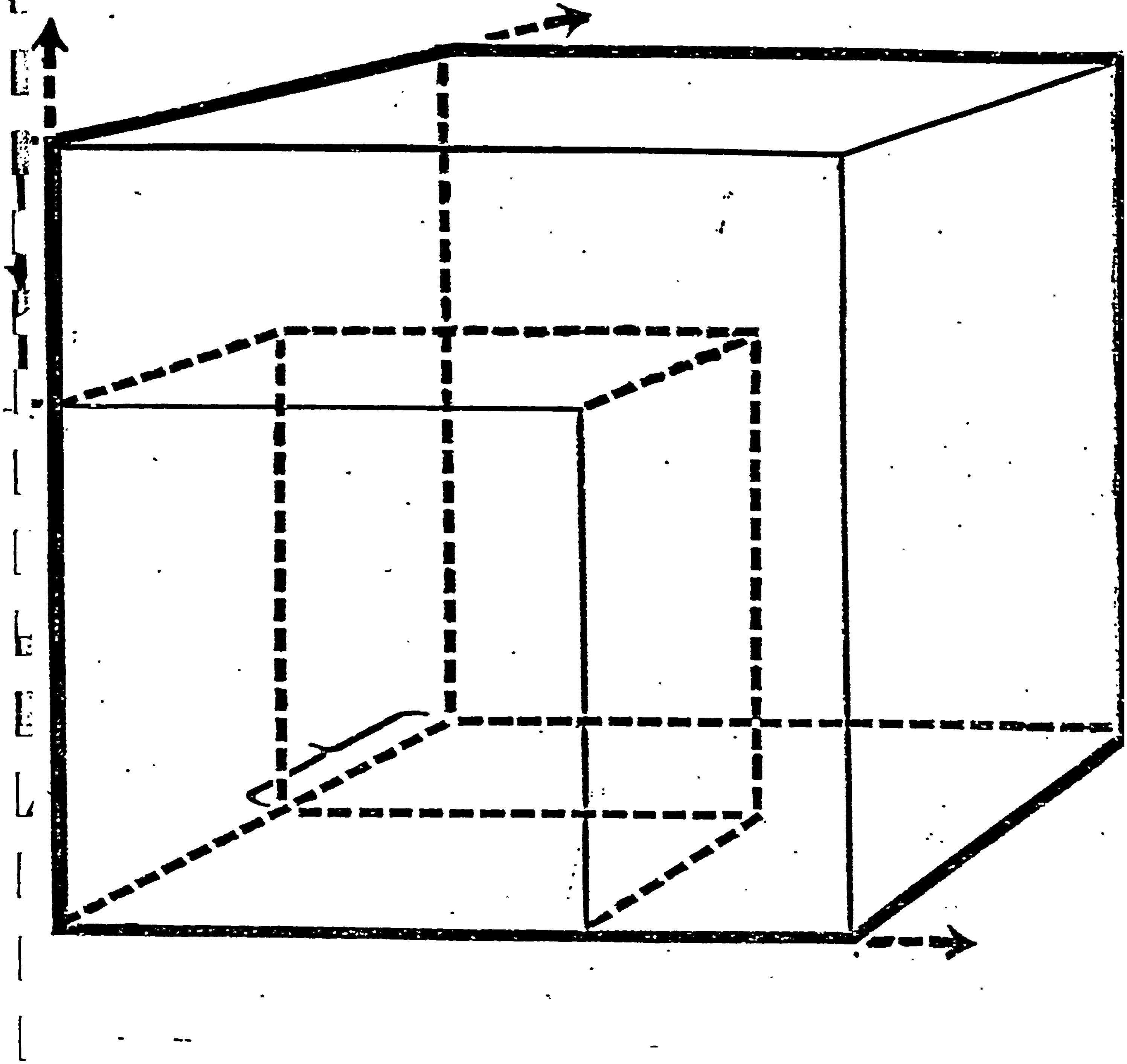
Better Utilization



Methods Improvements



Effect!



Productivity =

METHOD

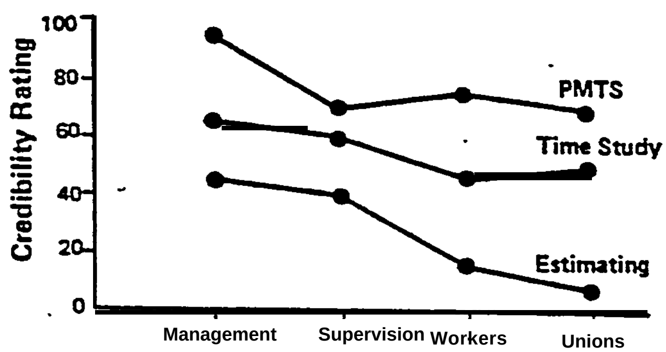
x UTILIZATION

x PERFORMANCE

= 1.15 X1.15 X 1.20

= INCREASE

MEASUREMENT SYSTEMS PREFERENCE SURVEY



Survey carried out by the University Research Institute USA 1978

DATA BANK	SUB-OPERATION

Title

ASSEMBLE JOINT TO PIPE FLANGE (24 HOLES OBSTRUCTED)
>600 MM PIPE BORE

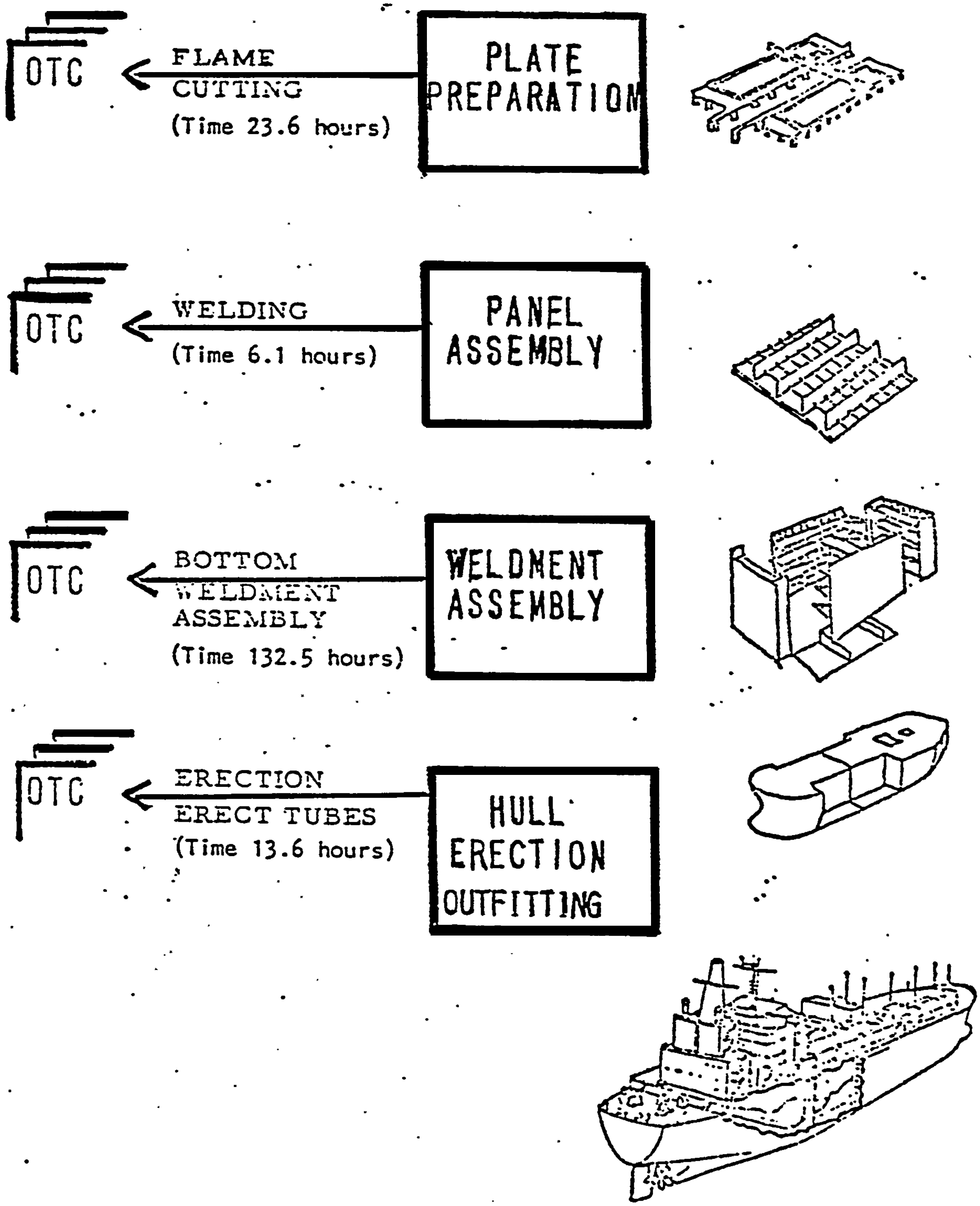
Description	Frequency	TMU
POSITION JOINT TO FLANGE & ALIGN HOLE		2 3
$A_3B_0G_1A_3B_0P_6A_0$ - $A_1B_0G_1M_1X_0I_1A_0$		
$A_1B_0G_1M_1X_0I_3A_0$		
GET BOLT - UNSCREW NUT & POSITION BOLT	24	8 1 6
$A_1B_0G_1A_1B_0F_0/L_{24}$ / $A_1B_0P_6A_0$		
PUSH BOLT THROUGH JOINT	24	2 4
$A_0B_0G_0M_1X_0I_0A_0$		
MOVE AROUND PIPE		3
$A_0B_0G_0A_3B_0P_0A$		
POSITION NUT & TIGHTEN	24	3 3 6 0
$A_1B_0G_1A_1B_0P_6/F_{131}$ / $A_0B_0P_0A_0$		
MOVE AROUND PIPE		3
$A_0B_0G_0A_3B_0P_0A_0$		
GET & ASIDE WRENCH		9
$A_3B_0G_1A_3B_0P_0A_0$ - $A_0B_0G_0A_1B_0P_1A_0$		
REPOSITION SPANNER ON NUT	24	3 5
$A_0B_0G_0A_1B_0P_3A_0$		
GET HAMMER - USE & ASIDE		1 5 3
$A_3B_0G_1A_3B_0P_0/F_{6x24}$ / $A_1B_0P_1A_0$		
MOVE AROUND PIPE		3
$A_0B_0G_0A_3B_0P_0A_0$		
		4 4 9 0

TOTAL TIME ≈ 0.449 HOURS
≈ 27 MINUTES

Total

Date	Signature	Approved
19. 9. 73.	[illegible]	[illegible]

SHIPBUILDING INDUSTRY
EXAMPLE:



WP MANUAL	OPERATION TIME CALCULATION	P 0 1 3 3 3
	FLAME CUTTING	2 3 6 1 6

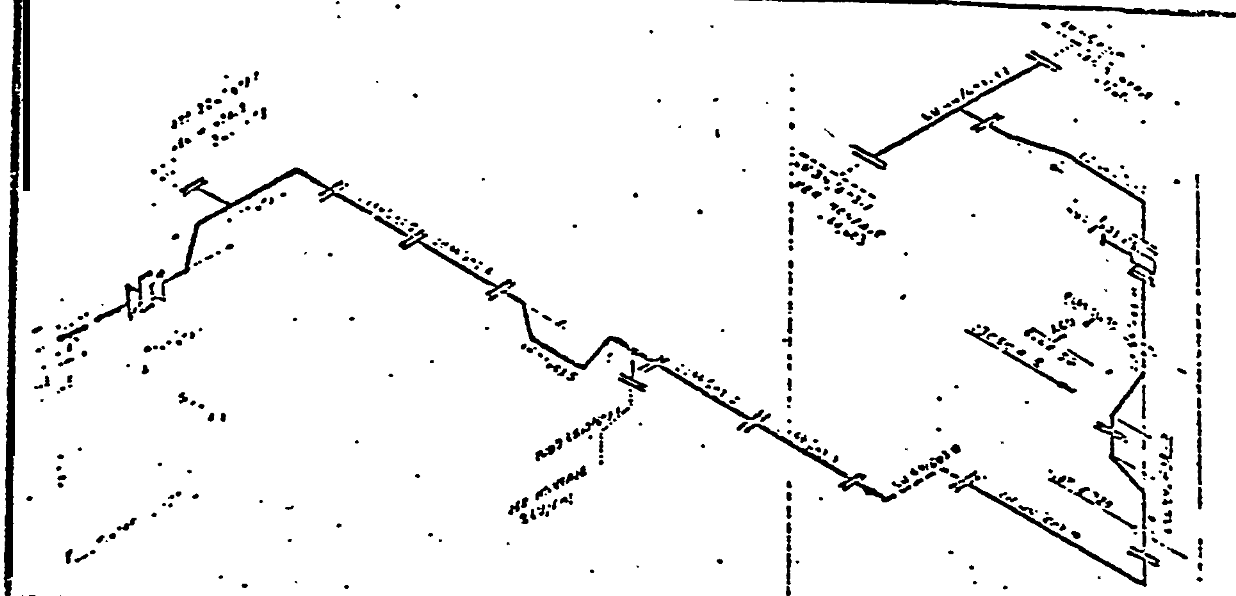
30 plates : 25mm : 15×2,5m

FLAME PLANE MACHINE

Prepare to burn	Prepare machine to burn			001	232	set up	15		3 480
	Set up nozzle for taper			002	60	cut			
	Preheat			000	20	cut			
Burn process time	"A" or "C" preparation	Plate thickness (mm)	12.5-17.5	010	57	metre			
			(17.5)-22.5	011	65	metre			
			(22.5)-27.5	012	63	metre			
			(27.5)-50	012	70	metre			
	"B" preparation	Plate thickness (mm)	12.5-17.5	020	60	metre			
			(17.5)-22.5	021	60	metre			
			(22.5)-27.5	022	73	metre	225		16 203
			(27.5-50	022	82	metre			
	1 in 3 taper	Plate thickness (mm)	17.5-22.5	030	85	metre			
			(22.5)-27	031	90	metre			
			(27.5)-50	032	120	metre			
							Total		19 683
Operation time incl. allowance factor = 1.20									23 610

731101

WP MANUAL	OPERATION TIME CALCULATION	WP 131404
	Operation: ERECT TUBES	Hours: 13 000
Product: Erect lubr. oil. pipes eng. room		2 men
Location: ENGINE ROOM		Drawing No.

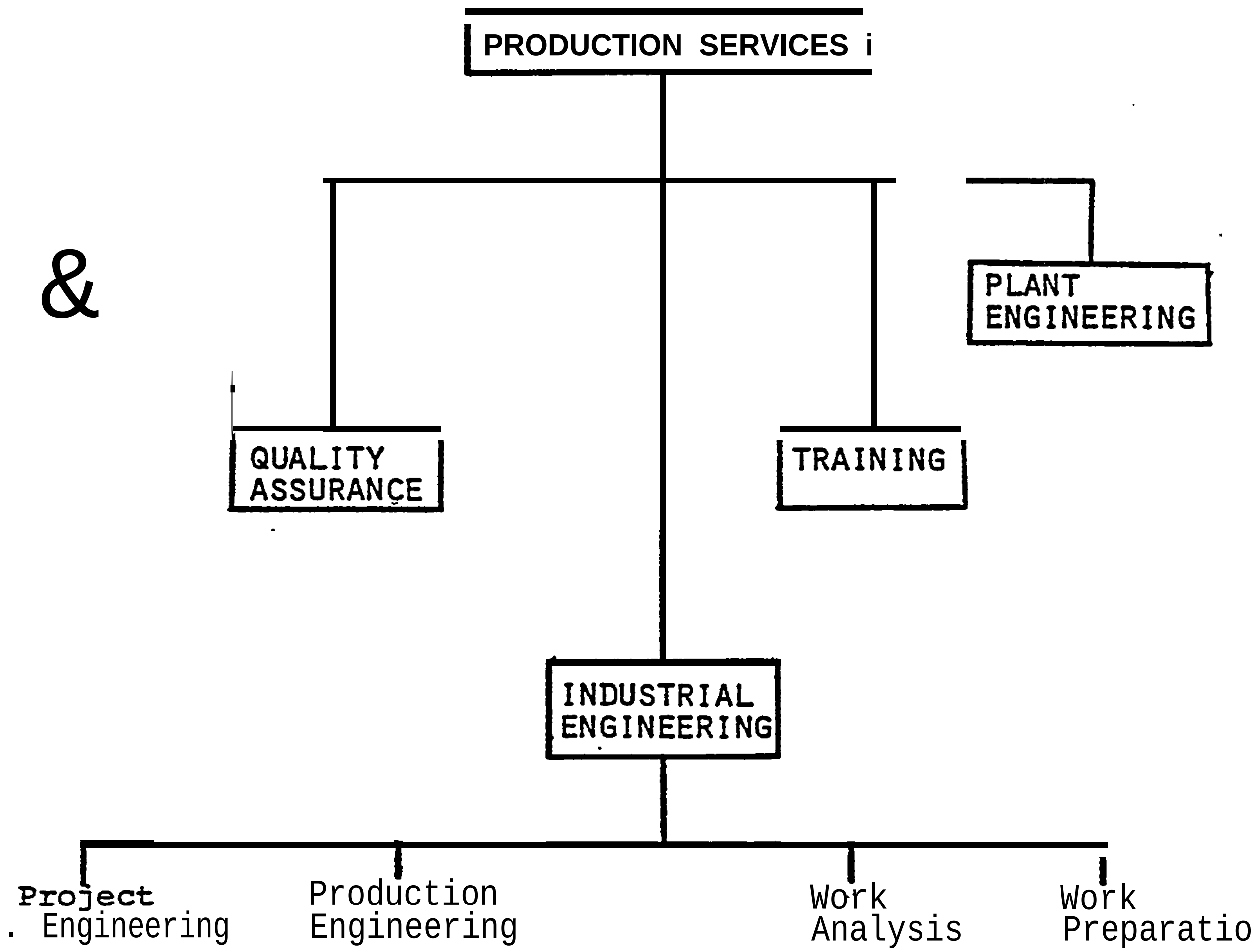


Final Sub Operations

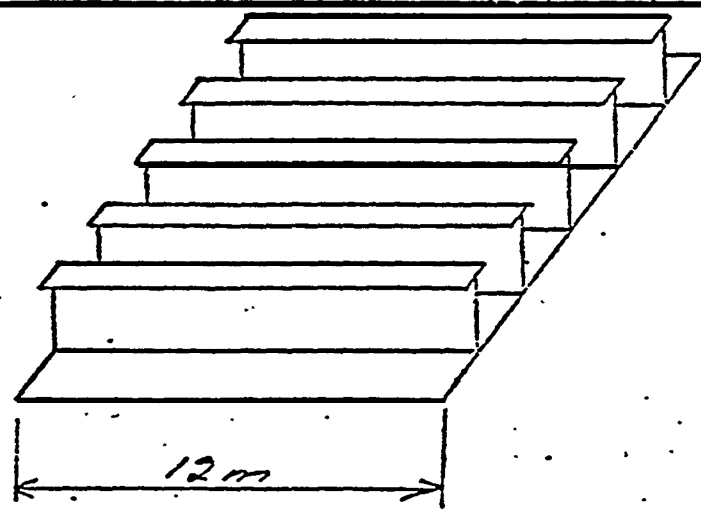
			No	TTU	Per	Frequency		
Position Tubes	Manual	$\emptyset < 100$ mm	01	140	Tube	13	1	820
	Crane	$\emptyset \geq 100$ mm	02	290	"			
	Yale	$100 \leq \emptyset \leq 150$ mm	03	560	"			
		$\emptyset > 150$ mm	04	690	"			
Position Valves Etc		$\emptyset < 100$ mm	05	140	Unit	2		280
		$100 \leq \emptyset < 300$ mm	06	560	"			
		$\emptyset \geq 300$ mm	07	680	"			
Assemble Flanges	Rachet Wrench	$\emptyset < 80$ mm	08	100	Fitting			
		$80 \leq \emptyset < 200$ mm	09	200	"	14	2	800
		$200 \leq \emptyset \leq 350$ mm	10	380	"			
		$350 < \emptyset \leq 450$ mm	11	570	"			
		$\emptyset > 450$ mm	12	900	"			
	Wrench	$\emptyset < 80$ mm	13	230	"			
		$80 \leq \emptyset < 200$ mm	14	600	"			
		$\emptyset \geq 200$ mm	15	900	"			
Position clips and cut supports (Clips with two supports has frequency 2)			16	250	Support	20	5	300
					Total		10	100
Operation time incl. allowance factor = 1.35							13	600

Date	Signature	Approved	Page
12-12-75	[illegible]		1/1

&


PRODUCTION SERVICES
QUALITY ASSURANCE
TRAINING
PLANT ENGINEERING
INDUSTRIAL ENGINEERING
Project Engineering
Production Engineering
Work Analysis
Work Preparation

WP MANUAL	OPERATION TIME CALCULATION	
	WELDING FLAT PANELS	6.120
Product: Panel no. 3826		3 men
Location: STATION IV PANEL LINE		4857326



			No	Time	Dim			
Prepare the job			01	400	Panel	1		400
TRANSPORT AND WELD THE SECTION	LENGTH OF SECTION		02	310	Sect			
		(8) - 9 m	03	840	"			
		(9) - 10 m	04	870	"			
		(10) - 11 m	05	910	"			
		(11) - 12 m	06	940	"	5		4700
		(12) - 13 m	07	970	"			
		(13) - 14 m	08	1000	"			
		(14) - 15 m	09	1030	"			
		(15) - 16 m	10	1070	"			
		(16) - 17 m	11	1100	"			
		(17) - 18 m	12	1130	"			

	Total	5100
Operation time incl. allowance factor = 1.20		6120

	Date	Signature	Approved	Page
				1

WP MANUAL	**WORK SHEET**	WP 0.5 0 1-2 | 1
	FINAL ASSEMBLY OF SHAPED SHELL WELDMENT	1325
WELDMENT 26 701-02		2 platers
FABRICATION SHOP		Drawing No 110701

PREPARE		start and finish job	01	2.5	job	1	2	5
		secure subassembly	02	0.2	piece	4		8
ALIGN FAIR AND TACK	SHELL SEAMS AND BUTTS	15 - 25 mm	11	0.21	metre	59	12	39
	SECTIONS	- 600 mm	15	0.19	metre	156	29	54
		(600) - 1000 mm	17	0.23	"			
	TRANSVERSES	to shell	21	0.28	metre	30	8	40
		to Bhd flush side	22	0.45	"			
		to Bhd stiffener side	23	0.54	"			
		- brackets to longl	24	0.2	piece	19	3	8
	BULKHEADS	to shell	31	0.31	metre	15	4	65
		- brackets to shell	32	0.2	piece	15	3	0
	GIRDERS OR STRINGERS	to shell	21	0.21	metre			
		to bulkhead - flush side	22	0.45	"			
		to bulkhead - [illegible]	[illegible]	[illegible]		15	8	10
		to transverse	43	0.55	"	15	9	15
		to shell longl	41	0.21	"			
		to bulkhead	42	0.15		130	19	5
		trip brackets to shell	44	0.1	piece	4	0	4
		trip brackets to longl.	24	0.2	"			
	BRACKETS	overhead/vertical	35	0.2	piece			
		flat	35	0.1	"			
		fitted on three sides	37	0.3	"	16	4	8
	SLOT LUGS		45	0.1	piece	32	3	2
	OIL TIGHT COLLARS	on OBP - 300 mm	49	0.2	"			
		on OBP (300) - 600 mm	50	0.3	"	16	4	8
		on OBP 600 - 1 600 mm	51	0.4	"			
		on T - bar	52	0.5	"			
	LIFTING LUGS		61	0.2	"	4		8

Total	98.88
Operation time incl. allowance factor = 1.32	132.52

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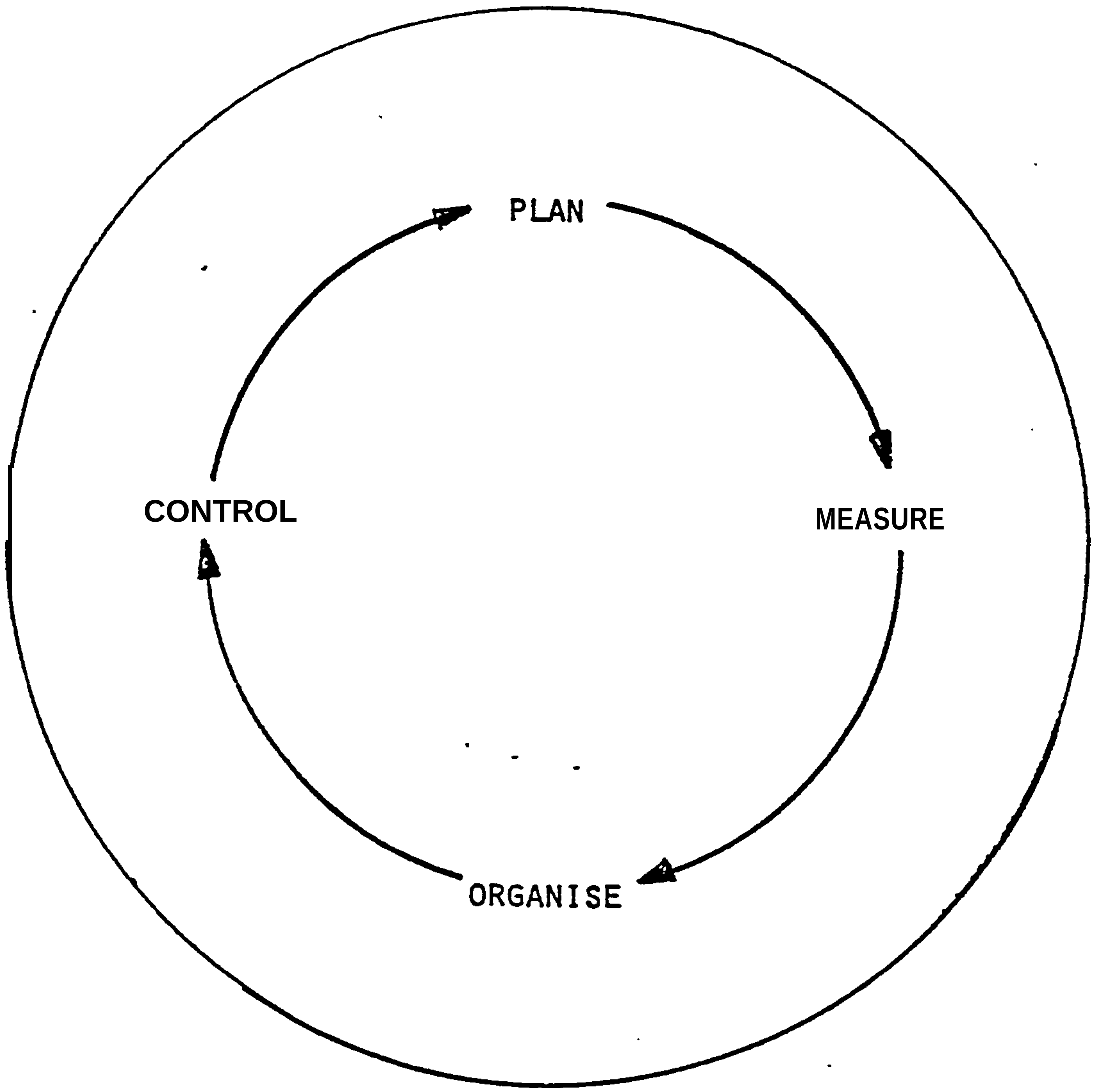
31/1-75	E.R.	[illegible]	1


PLAN
MEASURE
ORGANISE
CONTROL

NATIONAL SHIPBUILDING RESEARCH PROGRAM

GROUP TECHNOLOGY

DESIGN FOR PRODUCTION INTEGRATION

DESIGN FOR P

Journal of Ship Production. Vol. 4, No. 1, Feb. 1966, pp. 30-50

Group Technology in Shipbuilding

Thomas lamb[1]

The basic concepts of group technology are not new. The first use of the principles of group technology was described by an American, R. E. Flanders, in 1925. U.S. interest in group technology was slow to start, with initial flickerings in 1971 to 1973. If group technology is not new, why has it not been applied to the shipbuilding industry before now? In addition to the above-mentioned general lack of use, a complete lack of knowledge of it, and of its benefits is the most obvious reason. Actually, some shipyards in the world have utilized it and the paper describes some shipbuilding applications and gives

General

THE BASIC CONCEPTS Of group technology are not new. The first use of the principles of group technology was described by an American, R. E. Flantders [1][2], in 1925. The next significant development was published by J. C. Kerr [2] in Britain in 1938 and then in France by a Swedish engineer, A. Karling [3], in 1949. However the real development of group technology occurred in the Soviet Union in 1959 [4] and Germany in 1960 [5]. It was then utilized in factories in Estern Europe, and in the late 1960’s Its application began to increase in Britain and Western Europe. U.S. interest in group technology was slow to start with initial flickering in 1971 to 1973. Since 1976, the use of group technology in the United States has increased at an accelerated pace, as evidenced by 67 publications on group technology issued by the Society of Manufacturing Engineers over the last four years. This is partly due to its use with automated process planning.

As a science, it has not had the worldwide success of other modem techniques developed about the same time, such as operations research. This is mainly because of misunderstandings over what group technology is! In its most general sense, group technology is the integration of common problems, tasks, principles, and concepts to improve productivity. In a more restrictive sense it has been defined as a method to apply mass-production techniques to products that vary widely in type and quantity. Reference [6] defines group technology as the organization of production facilities in self-contained and self-regulating groups or cells, each of which undertakes the complete manufacture of a family of components with similar manufacturing characteristics. The cell staff are often each capable of using several machines or processes, so that there are usually fewer men than machines. It further describes the following characteristics, which distinguish group technology from conventional batch manufacturing systems

1. Components are classified into groups or families according to the production processes by which they are produced.
2. Work loads are balanced among the production groups into which production facilities are organized rather than between separate manufacturing operations.
3. The production groups —the people, machinery and components concerned-mw clearly identiilable on the shop floor, though each group may vary considerably in size. In some situations the machinery is arranged to provide a flow of work to optimize the operation of key machine tools by providing them with a full range of secondary machine tools to ensure a balanced input and smooth outflow of work. In other situations the machinery is arranged so that there can be a continuous flow of work from one machine to the next with the object of gaining some of the advantages of flow line production.
4. Each group works with a significant degree of autonomy.

Figure l(a) shows a typical shipyard process flow which is a "functional layout” and Fig. l(b) a modified process flow arranged as a “group layout” with “group” or "product” cells. Note the duplication of the machines in each cell. This can result in low machine utilization, but this is usual in group layouts. It is the overall productivity of the cell that is important, not machine utilization. It clearly shows how both the material and production control is simpler with the group layout. Grouping machines and arranging of process flow is only one facet of group technology and usually is performed on the basis of the results of grouping all the products and processes involved. Experience from users of group technology shows that its benefits can cover reduction in construction time, reduction of inventories and work in progress, more effective and economical inspection, and simplified planning, scheduling, and control systems.

Its limited use to date in general industry is pertly due to the fact that the foundation of group technology is classification and coding of like products and processes. Classification is a means of separating product data through similarities into groups or classes. Coding is the system which enables storing and retrieving the classified data so they can be organized, analyzed, and used for specific purposes. It should be remembered that group technology looks for the similarities and not the differences. The similar products are grouped in families and the families manufactured in groups of associated work stations. The necessary classification, coding, and analyzing involves significant effort. Because of the magnitude of the task, manual systems tended to deter the application. Nevertheless, many systems have been developed by various specialists in this field, Some companies used classification and coding systems to resolve manufacturing problems, only to forget them until another problem arose.

The development of group technology, understandably, ha been tied closely to the development of classification and

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[2]Numbers in brackets designate References at end of paper.

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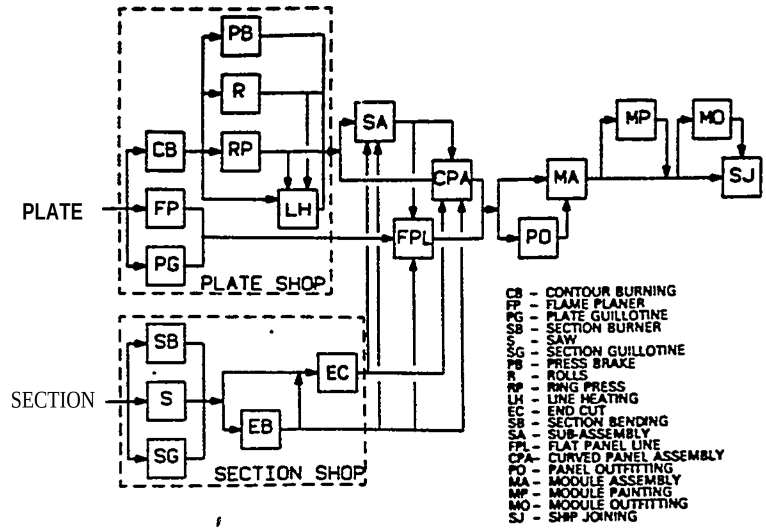


Fig. 1(a) Typical shipyard functional layout

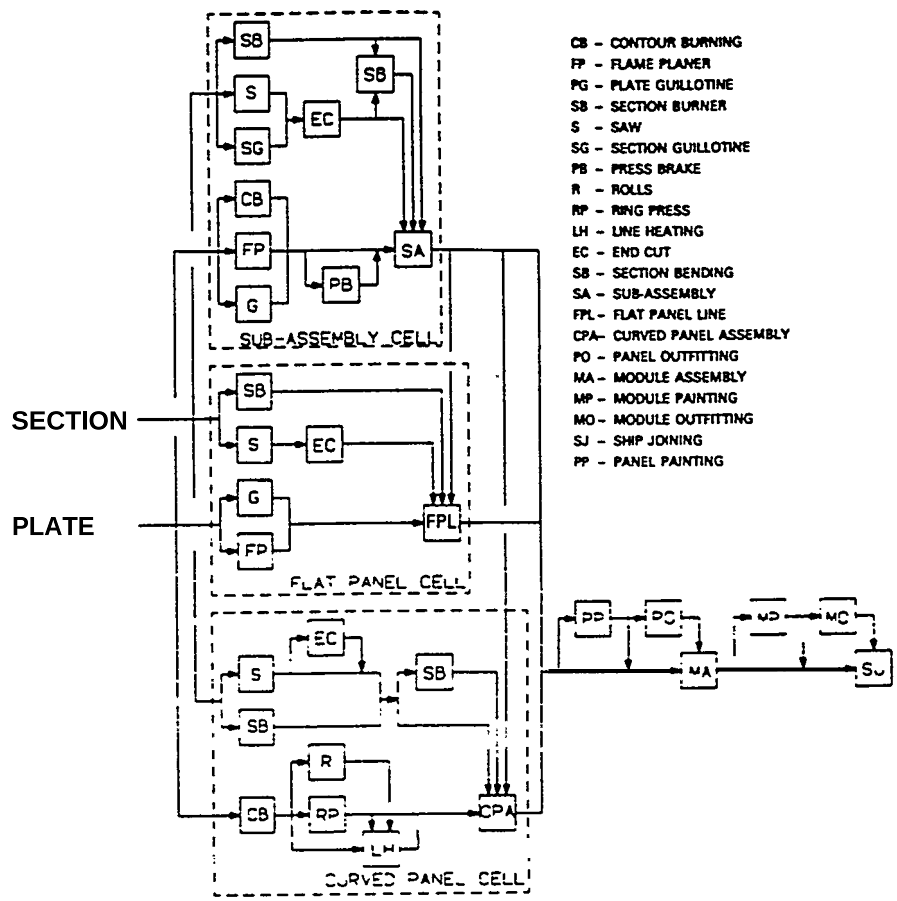


Fig. 1(b) Shipyard group layout

coding systems. Classification systems were developed for two basic group technology functions, namely product-variety reduction and grouping of parts for production. Product-variety reduction utilizes identification and retrieval of similar designs, whereas grouping of parts for production requires the selection of parts with similar processes. Many classification and coding systems have been developed and are described in the already-referenced textbooks on gr technology. Most of the systems are for machined parts, a few include sheet metal and piping fabrication. No them are directly applicable to the shipbuilding industry, some of them could be used as part of a shipyard syst and much can be learned from them when developing a s yard system.

Application of group technology to shipbuilding

If group technology is not new, why has it not been applied to the shipbuilding industry before now? In addition to the above mentioned general lack of use, a complete lack of knowledge of it and it benefits are the most obvious reasons. Even in the case of some shipyard managers who have knowledge of group technology, the inability of shipbuilding management to establish and enforce the detailed work breakdown and engineering required for its application prevented its use. It required the MarAd Technology Transfer program to introduce it to U.S. shipbuilders in the lHl Product *Work Breakdawn System Manual* [7]. The manual describes how to classify shipbuilding Products, and thus it is a partial application of group technology. Its usefulness is limited since it does not present an associated coding system. Group technology has been applied to shipbuilding in Japan [7], Britain [8-12] and in the U.S.S.R. [13]. These reports indicate that it has been applied successfully in the following shipbuilding areas:

- Design rationalization,
- Development of effective production planning systems by analysis of product size,, shapes, Variety, and processes,
- Structural material size variety reduction,
- Improved presentation of engineering information to the shop floor through classification and coding of products, and
- Improved shop floor organization and layout based on statistical analysis of the product processes and flow.

The reason for the current increase in interest in group technology is because it has been shown to be an effective way to assist industry to increase productivity. This must be the goal of every shipyard if they are to survive in the very competitive business of which they are a part. Group technology is an essential prerequisite to computer-tided process planning (CAPP), which in turn is essential for automated factories.

The way that group technology achieves improvements in productivity can be better understood if the various production organization types are briefly described, and their application to shipbuilding considered. Production organizations are usually grouped into five categories. These were well-defined by Marsh [14], and his titles are used as follows:

1. Craft organization (job shop): Organization using well-trained and experienced workers to perform many activities in one or a few locations. Most production decisions are left to the craftsman, who may approach each job in a different way. Required engineering data are minimum in scope and can be lacking in accuracy. Craft organizations are difficult to schedule and control.

2. Semi-process organization Organization utilizing well-trained and experienced workers, but attempting better planning and control by routing similar work processes to specific work areas. Requires more planning effort but scheduling and some control is attainable. Engineering has to be more detailed to enable planning to break down the work into task packages.

3. Process organization (batch): This is the complete use of specific work areas to perform specialized activities. This enables workers to be trained only in the special activity they are selected to perform. Scheduling and material control planning becomes more complex. Engineering is prepared for specialized processes rather than total product.

4. Product or group organization: This type of organization focuses on a type of product, such as flat panels, and links all the processes together to complete the product. It then combines a number of products to make a new larger pruduct such as an erection module and ultimately the sl hull. Planning is simpler because it follows a logical quence of events. Again the extent of worker training is ited to those processes utilized in a given work station. gineering is prepared to show the product to be process a given work station. Control can be precise due to the n available data points.

5. Mass-production organization: This type or orga tion maximizes the use of mechanization, continuous lines, and specialization of activities at sequential work tions. Material handling is decided at the time of the fac design. Engineering is more involved in machine ins tions, jig and tooling, and quality-control data.

The differences and relative effort for each type of c nization are summarized in Fig. 2, which is based on a ilar figure in reference [14]. The various organizations also been categorized by Hsrgroves, Teasdale, and Vau [15], and Table 1 is based on their presentation. It show productivity gap between organizations currently produ one-of products and mass production organizations. It shows the potential productivity improvement through g technology. Figure 3 is also taken from their work [5], it graphically illustrates the different processes. They in their paper.

It is more than likely that the concept of Group Tcchnology will to he the settling point of much of ship production activity in th ture.

The traditional shipyard was, as most shipyards are day, craft organized. In the past, this worked quite wel a number of reasons, including the following.

- Workers had pride in being craftsmen-and were pared to take the time to be trained. Five-year app ticeships were common.
- Employers were willing to invest time/money to their employees.
- The demand for ships was great enough that it was necessary to maximize productivity to survive.
- The trade unions in the shipbuilding industry res the changes that were necessary to improve the a cation of modem production techniques because usually involved demarcation issues.
- Engineering departments were incapable of provi the type of engineering information required for mo shipbuilding techniques.

Group technology, applied from engineering through to delivery, can provide the basis on which improved shipb ing production technology can be developed, and thus a increased productivity. The availability of computers an development of data-base technology have enabled the potential of group technology to be developed today. In the desire to use computers in manufacturing planning control necessitates better classification and coding and generates interest in group technology. As with any technique, there is the danger that only part of group nology will be used and thus that its full potential wil be developed. When group technology is introduced i shipyard, all departments are affected. This is indicate Fig. 4 and well described in most textbooks on group nology [16,17].

So far, most of the reported applications of group nology to shipbuilding have been in the area of ship s ture. It has been used to group structural parts by both geometry and processing characteristics for interim proc such as sub-assemblies, assemblies, and modules. A s hull is constructed from steel plate and sections which separately processed from the received material. The va of parts is large, whereas the variety of sub-assemblies assemblies is relatively small. The differences in size work content of the interim products results in the worl

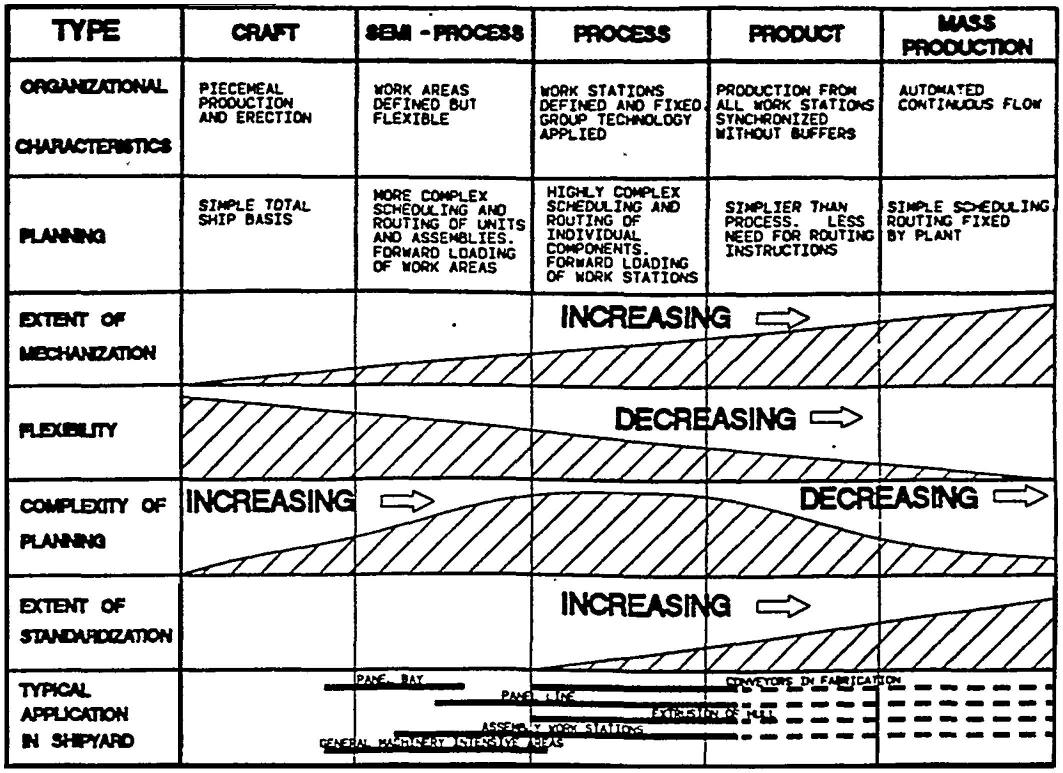


Fig. 2 **Transition from craft to mass production**

being suitable for normal continuous-flow processing. Group technology can partially overcome this problem by grouping the interim products into similar geometry or processing requirement groups or both so that the effective individual group volume increases to the extent that some of the benefits of continuous-flow processing can be obtained. If this can be done, improved productivity and shorter construction cycles are possible.

Group technology classification and coding systems should cover both product and process definition. The earlier separation of systems into product-variety reduction and product families for production should be avoided. The already-mentioned work in Britain by the University of Glasgow and the British Ship Research Association (BSRA) has developed a system for ship structure. It has been used for a number of applications, including the statistical analysis of *components* and their work content. This in turn has been used in the development of new shipyards. Reference [10] reviev eight classification and coding systems in use by Bri shipyards for ship structure, and was the basis for the fi system adoptd by BSRA. Reference [18] describes a p prietary claasification and coding system developed in Netherlands. It is a general format system allowing use input their own products and processes. The system is tegrated with a CAPP capability. A typical summary (structural component analysis is shown in Fig. 5, taken fı Reference [19]. Reference [20] details three application group technology to shipbuilding. These show how the stı tural classification and coding *system was* used to deve a data base of design and production information for var ship types. This enabled similarity of components for dif ent ships, structural process flow, work content, structu plate standardization, and new and existing facility anal to be determined. The analysis of the structural process f

Table 1 Production organization

Production Structure	"One-Of" / Infinite Variety	Wide Variety of Products / Low Quantity per Variety	Variety of Products / Medium Quantity per Variety	Few Kinds of Products / Large quantity per variety	Mas Product / Singl Produ Line
Production type		job shop	batch	flow	
Production layout		fixed position	process	product	
Production system		craft organized	process organized		
Pre-investment planning		low		product organized	
Operational planning		high	medium	low	
Relative productivity opportunity		low	medium	high	

← CURRENT PRODUCTIVITY GAP →

← POTENTIAL IMPROVEMENT →

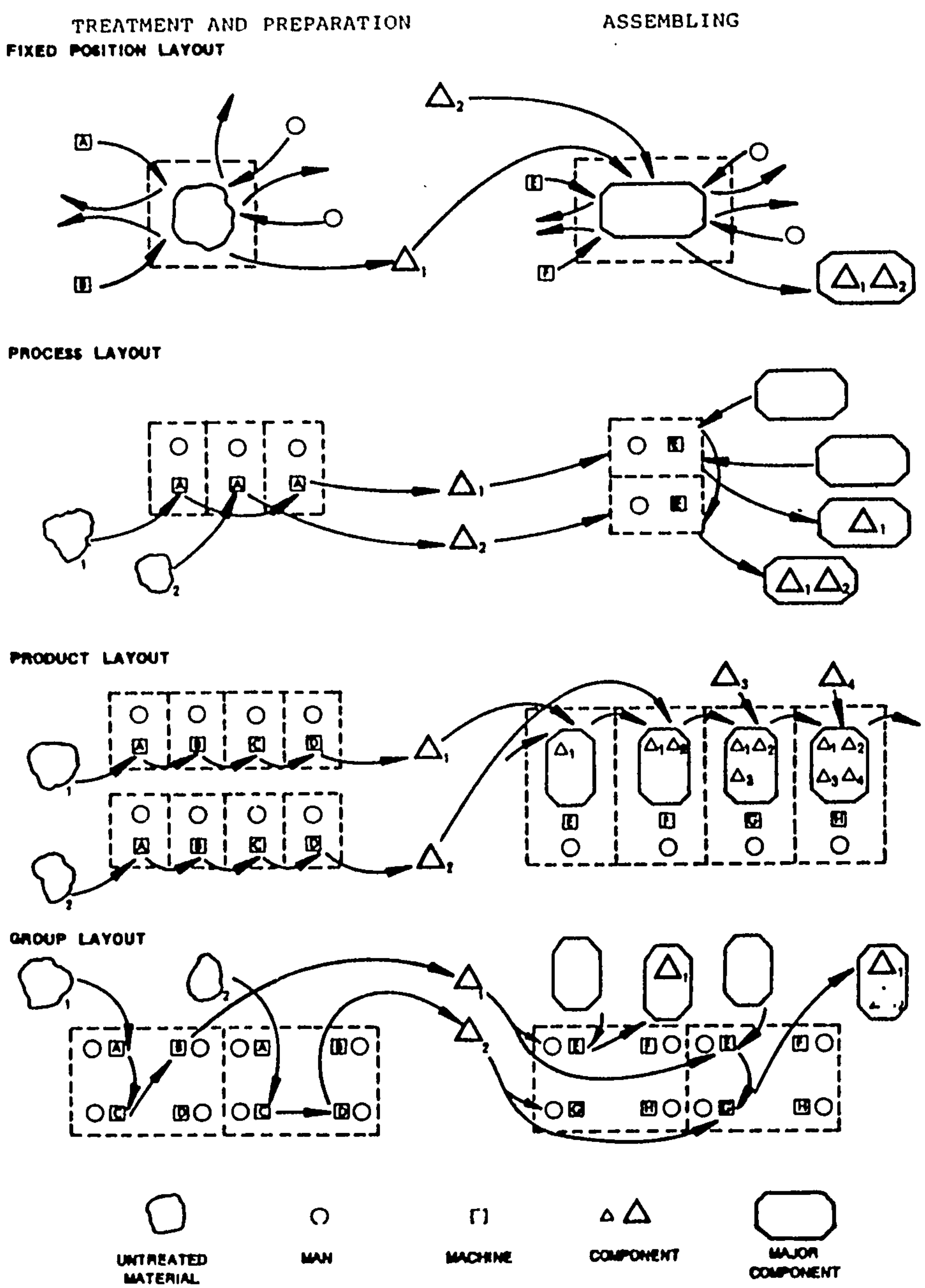


Fig. 3 Types of processes

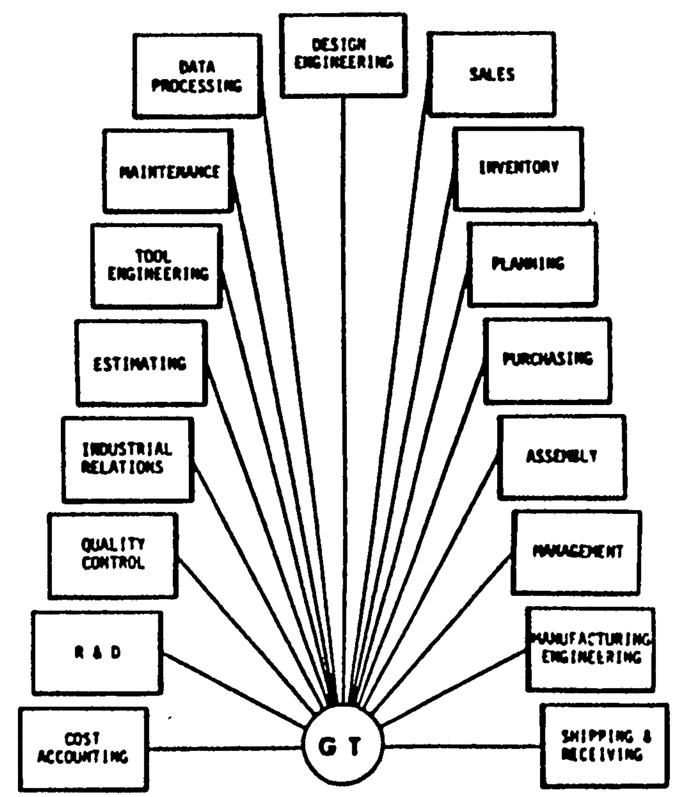
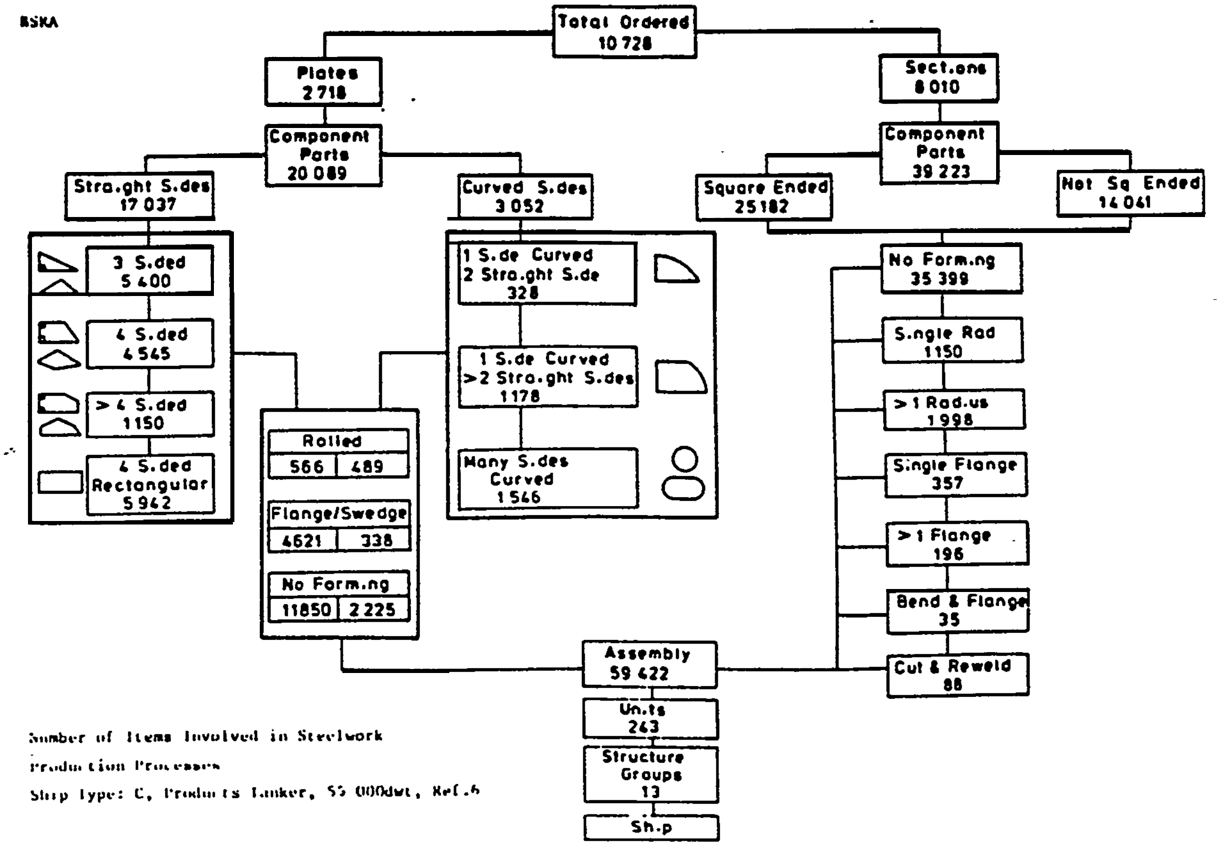


Fig. 4 Departments affected by group technology



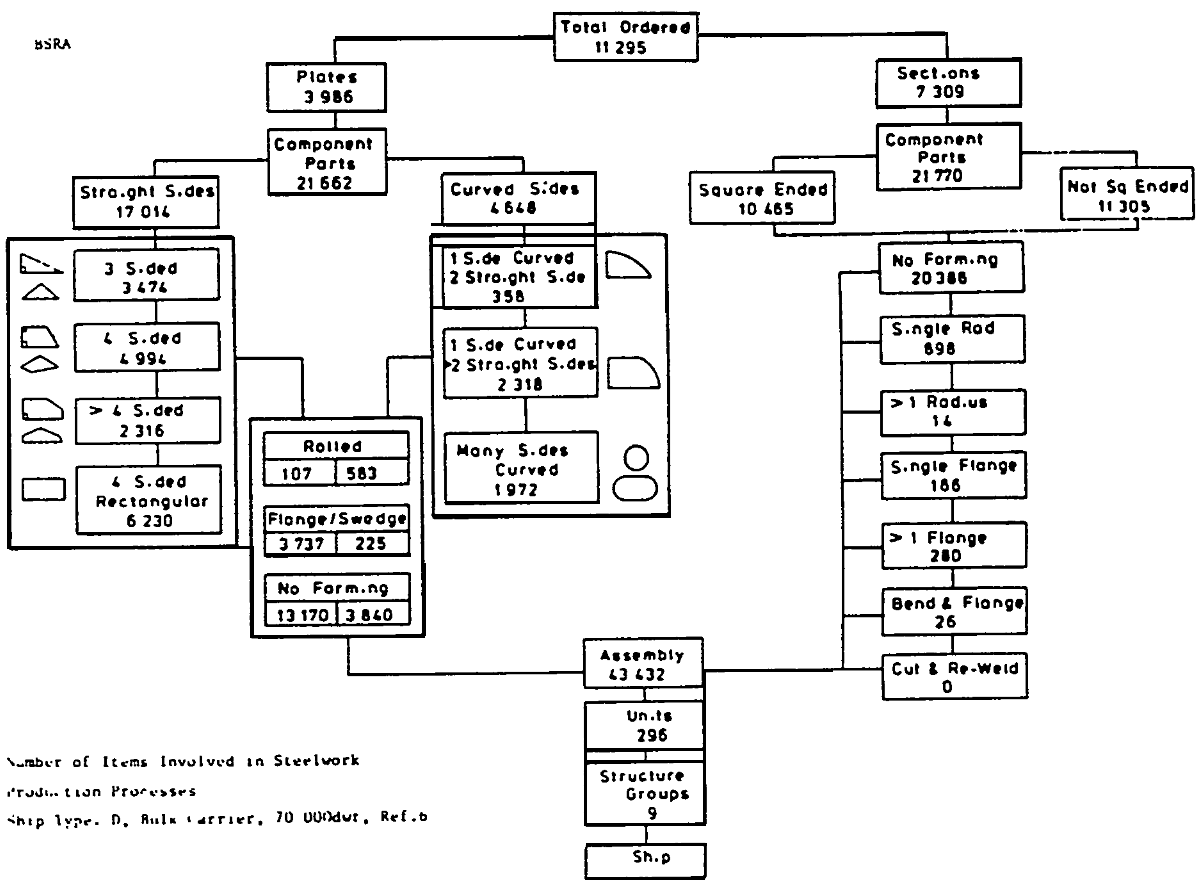


Fig. 5 Structual-component analysis summary

FIRST DIGIT	
BASED ON US NAVY SWBS	
0	
1	STRUCTURE
2	PROPULSION MACHINERY
3	ELECTRICAL
4	COMMAND & COMMUNICATION
5	AUXILIARY MACHINERY
6	OUTFIT
7	ARMAMENT
8	
9	SHIP ASSEMBLY & SUPPORT

SECOND DIGIT

FIRST DIGIT	1 STRUCTURE	2 PROPULSION MACHINERY	3 ELECTRICAL	4 COMMAND & COMMUNICATION	5 AUXILIARY MACHINERY	6 OUTFIT	7 ARMAMENT	9 SHIP ASSEMBLY & SUPPORT
0	PLATE	CONTROLS	GENERATORS	SAFETY & SECURITY	HVAC	HULL MARKING		STAGING
1	SECTION	ENERGY GENERATOR	MOTORS	COMMAND & CONTROL	SALT WATER SYSTEMS	SHIP FITTINGS	GUNS & AMMUNITION	TEMPORARY SERVICES
2	SUB-ASSEMBLY	PROPULSION UNITS	TRANSFORMERS	NAVIGATION	FRESH WATER SYSTEMS	COMPARTMENT-ATION	MISSILES & ROCKETS	MATERIAL HANDLING & REMOVAL
3	ASSEMBLY	TRANSMISSION	SWITCHBOARDS	INTERIOR COMMUNICATION	FUEL SYSTEMS	PRESERVATION & COVERINGS	MINES	CLEANING SERVICES
4	FOUNDATION	PROPULSOR	CONTROLLERS	EXTERIOR COMMUNICATION	L O SYSTEMS	LIVING SPACES	DEPTH CHARGES	MOLDS & TEMPLATES
5	CASTINGS	PROPULSION SUPPORT	PANELS	SURFACE SURVIELANCE	AIR, GAS & MISC. FLUID SYSTEMS	SERVICE SPACES	TORPEDOES	JIGS & FIXTURES
6	FLAT PANEL	FUEL & L O SUPPORT	CABLE	UNDERWATER SURVIELANCE	SHIP CONTROL	WORKING SPACES	SMALL ARMS & PYROTECHNICS	LAUNCHING
7	CURVED PANEL	AUXILIARY PROPULSION	LIGHTING	COUNTER-MEASURES	RAS/FAS	STOWAGE SPACES	CARGO MUNITIONS	DRYDOCKING
8	HULL MODULE	OPERATING FLUIDS		WEAPON CONTROL	MECHANICAL HANDLING		AIRCRAFT RELATED WEAPONS	TESTS
9	DECKHOUSE MODULE	SPARE PARTS	SPARE PARTS	SPARE PARTS	SPARE PARTS	SPARE PARTS	SPARE PARTS	TRIALS

Fig. 6 Shipbuilding classification and coding system (SCCS)

showed that no component required more than two welding processes and that 75 percent of all components had only one welding process before delivery to the module assembly.

It is not known if the BSRA structural classification and coding system has been expanded to cover all shipyard products and processes. However, it is essential that a complete system be developed to allow the full benefit of group technology to be achieved. With this in mind, the author developed a shipbuilding classification and coding system (SCCS). Figure 6 details the system, which uses up to 17 digits, all numbers. The number of digits used varies depending on the product. However, a full 17-digit field is always used. For example, a structural plate product uses all 17 digits, whereas a sub-assembly uses only 11 of the digits for meaningful data. The first to the tenth digits are used for design classification, and the eleventh to seventeenth digits are used for processing classification. The use of the system should be obvious from the data given in the figure. For structure, the following applies:

First Digit = Ship group The subdivision of the ship into major systems. The U.S. Navy Ship Work Breakdown Structure first digit groups are used because of the U.S. shipbuilding industry's familiarity with it.

Second Digit = Base Product: The subdivision into products as received by the shipyard, such as plate and sections.

Third Digit = Type: The subdivision of base products into the various types that they can be. For example, sections could be flat bar, angle, channel, tee, etc.

Fourth Digit = Material: Defines the material in terms of specification and quality.

Fifth Digit = Size classification, length.

The sixth through tenth digits are used for different classification depending on the first two digits as follows:

Sixth Digit = For Plate, width for sections, web depth.

Seventh Digit = For Plate, thickness; for sections, flange width.

Eighth Digit = For Plate, shape; for sections, web thickness.

Ninth Digit = For Plate, holes and slow, for sections, flange thickness.

Tenth Digit = For Plate, edge preparation for sections, end cut.

The eleventh through seventeenth digits are used to classify the processes used to fabricate and install the products to build a ship as follows:

Eleventh Digit = Pre-processing treatment: Identifies the various preprocessing treatment for all products.

Twelfth Digit = Cutting Identifies cutting processes.

Thirteenth Digit = Forming Identifies forming processes.

Fourteenth Digit = Connection type: Identifies the connection type used to attach the classified product.

Fifteenth Digit = Work position Identifies the work position for the connection of the product.

Sixteenth Digit = Work station Identifies the work station at which the product is installed.

Seventeenth Digit = Equipment used Identifies the type of equipment used at the work station to make or install the product.

(text continued on page 46)

1 ST DIGIT - I - STRUCTURE **2ND DIGIT** - 0 - PLATE

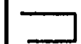
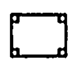
	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12TH	13TH	14TH	15TH	16TH	17TH
	TYPE	MATERIAL	LENGTH	WIDTH	THICKNESS	SHAPE	HOLES & SLOTS	EDGE PREPARATION	PRE-PROCESSING TREATMENT	CUTTING	FORMING	CONNECTION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0	STANDARD	STEEL "A"	$0 \leqslant 2$	$0 \leqslant 1$	$.125 \leqslant .25$		NONE		NONE	NONE	NONE	NONE	DOWN HAND	SUB-ASSEMBLY	NONE
1	DIAMOND RAISED PATTERN	STEEL "B"	$2 \leqslant 4$	$1 \leqslant 2$	$.25 \leqslant .5$				STRAIGHTENING ROLLS	SHEER	FLANGE	FILLET WELD NON-CONT	VERTICAL	ASSEMBLY	OPTICAL MARKING MACHINE
2	GALVANIZED	STEEL "D"	$4 \leqslant 8$	$2 \leqslant 4$	$.375 \leqslant .5$				BLAST	SAW	PRESS	FILLET WELD CONTINUOUS	OVERHEAD	FOUNDATION	N/C BURNING MACHINE
3	CLAD	STEEL "E"	$8 \leqslant 12$	$4 \leqslant 6$	$.5 \leqslant .625$				PRIME	MANUAL BURN	ROLL	BUTT WELD	ROTATE	FLAT PANEL LINE	ROLLS
4	EXPANDED	STEEL "DS"	$12 \leqslant 20$	$6 \leqslant 8$	$.625 \leqslant .75$			0 + 1	SPECIAL MARKING PRIME	FRAME PLANNER	RING PRESS	ONE SIDE BUTT WELD	TURN	CURVED PANEL LINE	PRESS
5	PERFORATED	STEEL "CS"	$20 \leqslant 30$	$8 \leqslant 9$	$.75 \leqslant 1.$			0 + 2	1+2+3	OPTICAL BURN	LINE HEAT	PLUG WELD	0 + 3	PANEL OUTFITTING	RING PRESS
6	DATA COUPLE	STEEL "H32"	$30 \leqslant 40$	$9 \leqslant 10$	$1. \leqslant 1.25$		1 + 2	1 + 2	2 + 3	N/C BURN	3 + 4	FAIR/FILL WELD	0 + 4	MODULE ASSEMBLY	STICK WELD GRAVITY FEED
7	0 + 1	STEEL "H36"	$40 \leqslant 50$	$10 \leqslant 11$	$1.25 \leqslant 1.5$		1+2+3	3 + 4	1+2+4	FITTING CUTTING	3 + 5	BOLT	1 + 3	MODULE OUTFITTING	MIG WELD
8	1 + 2	STEEL HY-80/100	$50 \leqslant 60$	$11 \leqslant 12$	$1.5 \leqslant 2.$		2 + 3	3 + 5	2 + 4	DRILL	4 + 5	RIVET	1 + 4	SHIP ASSEMBLY	TIG WELD
9	2 + 5	ALUMINUM	$\geqslant 60$	$\geqslant 12$	$\geqslant 2.$		4 + 5	3 + 6		ROUTER		OTHER	2 + 3	SHIP OUTFITTING	SUB-ARC WELD

Fig. 6 (*continued*)

1 ST DIGIT - I -STRUCTURE **2ND DIGIT** - I -SECTION

	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12 TH	13 TH	14 TH	15 TH	16 TH	17 TH
	TYPE	MATERIAL	LENGTH	WEB DEPTH	FLANGE WIDTH	WEB THICKNESS	FLANGE THICKNESS	END CUT	PRE-PROCESSING TREATMENT	CUTTING	FORMING	CONNECTION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0	FLAT BAR	STEEL "A"	0 ⩽ 2	0 ⩽ 1	0 ⩽ 1	⩽.125	⩽.125	SQUARE	NONE	NONE	NONE	NONE	DOWN HAND	SUB-ASSEMBLY	NONE
1	ROUND BAR	STEEL "B"	2 ⩽ 4	1 ⩽ 2	1 ⩽ 2	.125<.25	.125<.25	ONE SNIPE	STRAIGHT-ENING ROLLS	SHEER	ROLL BEND	FILLET WELD NON-CONT	VERTICAL	ASSEMBLY	SHEER
2	SEGMENTAL BAR	STEEL "D"	4 ⩽ 8	2 ⩽ 4	2 ⩽ 4	.25 <.5	.25 <.5	TWO SNIPE	BLAST	SAW	PRESS BEND	FILLET WELD CONTINUOUS	OVERHEAD	FOUNDATION	AUTO SHEER
3	ANGLE	STEEL "E"	8 ⩽ 12	4 ⩽ 6	4 ⩽ 6	.375<.5	.375<.5	LAP CUT	PRIME	MANUAL BURN	LINE HEAT BEND	BUTT WELD	ROTATE	FLAT PANEL LINE	SAW
4	CHANNEL	STEEL "DS"	12⩽ 20	6 ⩽ 8	6 ⩽ 8	.5 <625	.5 <.625	INTERFACE	SPECIAL MARKING PRIME		N/C BEND	2 + 4	TURN	CURVED PANEL LINE	AUTO SAW
5	"I" OR WIDE FLANGE	STEEL "CS"	20⩽ 30	8 ⩽ 9	8 ⩽ 9	.625<.75	.625<.75	1 + 3	1+2+3		MANUAL TWIST	3 + 4	0 + 3	PANEL OUTFITTING	STICK WELD GRAVITY FEED
6	TEE	STEEL "H32"	30⩽ 40	9 ⩽ 12	9 ⩽ 12	.75 <1.	.75 <1.		2 + 3		N/C TWIST		0 + 4	MODULE ASSEMBLY	MIG WELD
7	TEE CUT FROM "I" OR WIDE FLANGE	STEEL "H36"	40⩽ 50	12⩽ 18	12⩽ 18	> 1.	1. <1.25		1+2+4	FITTING CUTTING	4 + 5	BOLT	1 + 3	MODULE OUTFITTING	TIG WELD
8	TUBE	STEEL HY-80/100	50⩽ 60	18⩽ 24	18⩽ 24		1.25<1.5		2 +4	DRILL		RIVET	1 + 4	SHIP ASSEMBLY	SUB-ARC WELD
9	PIPE	ALUMINUM	> 60	> 24	> 24		> 1.5					OTHER	2 + 3	SHIP OUTFITTING	ROBOTIC WELDER

Fig. 6 (*continued*)

1 ST DIGIT -1-STRUCTURE 2ND DIGIT -2-SUB-ASSEMBLY

	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12TH	13TH	14TH	15TH	16TH	17TH
	TYPE	MATERIAL	LENGTH	WIDTH	DEPTH	SUB-ASSY SHAPE	WEIGHT	NUMBER OF PARTS PER SUB-ASSY	POST ASSEMBLY TREATMENT	CUTTING		CONNECT-ION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0	FLOOR	MILD STEEL	< 2	< 1	< .25		< 50	< 2	NONE	NONE		NONE	DOWN HAND		NONE
1	WEB FRAME	H. S. STEEL	2 < 4	1 < 2	.25 < .5		50 < 100	2 < 3	WIRE BRUSH	FITTING CUTTING		FILLET WELD NON-CONT	VERTICAL	ASSEMBLY	AUTO ASSEMBLY
2	BULKHEAD WEB	H. Y. STEEL	4 < 8	2 < 3	.5 < .75		100 < 200	3 < 4	BLAST			FILLET WELD CONTIN-UOUS	OVERHEAD	FOUNDAT-ION	STICK WELD GRAVITY FEED
3	SHELL STRINGER	ALUMINUM	8 < 12	3 < 5	.75 < 1		200 < 500	4 < 5	PRIME			BUTT WELD	ROTATE	FLAT PANEL LINE	MIG WELD
4	BULKHEAD STRINGER	OTHER	12 < 20	5 < 10	1 < 2		500 < 1000	5 < 7	FINISH COATING			ONE SIDE BUTT WELD	TURN	CURVED PANEL LINE	TIG WELD
5	BOTTOM GIRDER		20 < 30	10 < 15	2 < 3		1000 < 2000	7 < 10	1 + 3			PLUG WELD	0 + 3	PANEL OUTFITT-ING	SUB-ARC WELD
6	DECK GIRDER		30 < 40	15 < 20	3 < 5		2000 < 5000	10 < 15				FAIR/FILL WELD	0 + 4	MODULE ASSEMBLY	ROBOTIC WELD
7	DECK TRANSVERSE		40 < 50	20 < 30	5 < 10		5000 < 10000	15 < 20				BOLT	1 + 3	MODULE OUTFITT-ING	
8	BULWARK		50 < 60	30 < 40	> 10		10000 < 20000	20 < 30				RIVET	1 + 4	SHIP ASSEMBLY	
9			> 60	> 40			> 20000	> 30				OTHER	2 + 3	SHIP OUTFITT-ING	

Fig. 6 *(continued)*

1 ST DIGIT - 1 - STRUCTURE **2ND DIGIT** - 2 - SUB-ASSEMBLY

	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12TH	13TH	14TH	15TH	16TH	17TH
	TYPE	MATERIAL	LENGTH	WIDTH	DEPTH	SUB-ASSY SHAPE	WEIGHT	NUMBER OF PARTS PER SUB-ASSY	POST ASSEMBLY TREATMENT	CUTTING		CONNECT-ION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0	FLOOR	MILD STEEL	< 2	< 1	< .25		< 50	< 2	NONE	NONE		NONE	DOWN HAND		NONE
1	WEB FRAME	H. S. STEEL	2 < 4	1 < 2	.25 < .5		50 < 100	2 < 3	WIRE BRUSH	FITTING CUTTING		FILLET WELD NON-CONT	VERTICAL	ASSEMBLY	AUTO ASSEMBLY
2	BULKHEAD WEB	H. Y. STEEL	4 < 8	2 < 3	.5 < .75		100 < 200	3 < 4	BLAST			FILLET WELD CONTIN-UOUS	OVERHEAD	FOUNDAT-ION	STICK WELD GRAVITY FEED
3	SHELL STRINGER	ALUMINUM	8 < 12	3 < 5	.75 < 1		200 < 500	4 < 5	PRIME			BUTT WELD	ROTATE	FLAT PANEL LINE	MIG WELD
4	BULKHEAD STRINGER	OTHER	12 < 20	5 < 10	1 < 2		500 < 1000	5 < 7	FINISH COATING			ONE SIDE BUTT WELD	TURN	CURVED PANEL LINE	TIG WELD
5	BOTTOM GIRDER		20 < 30	10 < 15	2 < 3		1000 < 2000	7 < 10	1 + 3			PLUG WELD	0 + 3	PANEL OUTFITT-ING	SUB-ARC WELD
6	DECK GIRDER		30 < 40	15 < 20	3 < 5		2000 < 5000	10 < 15				FAIR/FILL WELD	0 + 4	MODULE ASSEMBLY	ROBOTIC WELD
7	DECK TRANSVERSE		40 < 50	20 < 30	5 < 10		5000 < 10000	15 < 20				BOLT	1 + 3	MODULE OUTFITT-ING	
8	BULWARK		50 < 60	30 < 40	> 10		10000 < 20000	20 < 30				RIVET	1 + 4	SHIP ASSEMBLY	
9			> 60	> 40			> 20000	> 30				OTHER	2 + 3	SHIP OUTFITT-ING	

Fig. 6 (continued)

1 ST DIGIT - 1 - STRUCTURE **2ND DIGIT** -3-ASSEMBLY

	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12TH	13TH	14TH	15TH	16TH	17TH
	TYPE	MATERIAL	LENGTH	WIDTH	DEPTH	ASSEMBLY SHAPE	WEIGHT	NUMBER OF PARTS PER ASSEMBLY	POST ASSEMBLY TREATMENT	CUTTING		CONNECT-ION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0	SHELL	MILD STEEL	< 2	< 1	< .25		< 500	< 2	NONE	NONE		NONE	DOWN HAND		NONE
1	TRANSVERSE BULKHEAD	H. S. STEEL	2 < 4	1 < 2	.25 < .5		500 < 1000	2 < 3	WIRE BRUSH	FITTING CUTTING		FILLET WELD NON-CONT	VERTICAL		AUTO ASSEMBLY
2	LONGITUD-INAL BULKHEAD	H. Y. STEEL	4 < 8	2 < 3	.5 < .75		1000 < 2000	3 < 4	BLAST			FILLET WELD CONTIN-UOUS	OVERHEAD		STICK WELD GRAVITY FEED
3	TANKTOP	ALUMINUM	8 < 12	3 < 5	.75 < 1		2000 < 5000	4 < 5	PRIME			BUTT WELD	ROTATE	FLAT PANEL LINE	MIG WELD
4	FLAT	OTHER	12 < 20	5 < 10	1 < 2		5000 < 10000	5 < 7	FINISH COATING			ONE SIDE BUTT WELD	TURN	CURVED PANEL LINE	TIG WELD
5	HULL DECK		20 < 30	10 < 15	2 < 3		10000 < 20000	7 < 10	1 + 3			PLUG WELD	0 + 3	PANEL OUTFITT-ING	SUB-ARC WELD
6	HOUSE SIDE		30 < 40	15 < 20	3 < 5		20000 < 30000	10 < 15				FAIR/FILL WELD	0 + 4	MODULE ASSEMBLY	ROBOTIC WELD
7	HOUSE DECK		40 < 50	20 < 30	5 < 10		30000 < 50000	15 < 20				BOLT	1 + 3	MODULE OUTFITT-ING	
8	BULWARK		50 < 60	30 < 40	10 < 20		50000 < 100000	20 < 30				RIVET	1 + 4	SHIP ASSEMBLY	
9	TRUNK		> 60	> 40	> 20		> 100000	> 30				OTHER	2 + 3	SHIP OUTFITT-ING	

Fig. 6 (*continued*)

1 ST DIGIT - 1 - STRUCTURE **2ND DIGIT** - 7 - HULL MODULE - 8 - DECKHOUSE MODULE

	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12TH	13TH	14TH	15TH	16TH	17TH
	TYPE	MATERIAL	LENGTH	WIDTH	DEPTH	MODULE SHAPE	WEIGHT	NUMBER OF PARTS PER MODULE	POST ASSEMBLY TREATMENT	CUTTING		CONNECTION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0	SINGLE BOTTOM	MILD STEEL	< 10	< 10	< 1	2 D PANEL	< 500	< 2	NONE	NONE		NONE	DOWN HAND		NONE
1	DOUBLE BOTTOM	H. S. STEEL	10 < 20	10 < 20	1 < 2	RECTANGULAR BLOCK	2000 <5000	2 < 3	WIRE BRUSH	FITTING CUTTING		FILLET WELD NON-CONT	VERTICAL		AUTO ASSEMBLY
2	DEEP TANK	H. Y. STEEL	20 < 30	10 < 15	2 < 3	BLOCK WITH ONE SIDE CURVED	5000 < 10000	3 < 5	BLAST			FILLET WELD CONTINUOUS	OVERHEAD		STICK WELD GRAVITY FEED
3	WING TANK	ALUMINUM	30 < 40	15 < 20	3 < 5	CYLINDRICAL BLOCK	10000 < 20000	5 < 10	PRIME			BUTT WELD	ROTATE		MIG WELD
4	DECK	OTHER	40 < 50	20 < 30	5 < 10		20000 < 30000	10 < 15	FINISH COATING			ONE SIDE BUTT WELD	TURN		TIG WELD
5	SIDE SHELL		50 < 60	30 < 40	10 < 20		30000 < 50000	15 < 20	1 + 3			PLUG WELD	0 + 3		SUB-ARC WELD
6	HATCHWAY		60 < 70	40 < 50	20 < 30		50000 < 100000	20 < 30				FAIR/FILL WELD	0 + 4		CONSUMABLE NOZZLE
7			70 < 80	50 < 60	30 < 40		100000 < 150000	30 < 40				BOLT	1 + 3	MODULE OUTFITTING	ROBOTIC WELD
8	BULWARK		80 < 90	60 < 70	40 < 50		150000 < 250000	40 < 50				RIVET	1 + 4	SHIP ASSEMBLY	
9	TRUNK		> 90	> 70	> 50		> 250000	> 50				OTHER	2 + 3	SHIP OUTFITTING	

Fig. 6 *(continued)*

1 ST DIGIT -1- STRUCTURE **2ND DIGIT** -4- FOUNDATIONS

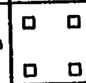
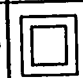
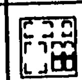
	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12TH	13TH	14TH	15TH	16TH	17TH
	SYSTEM	TYPE	MATERIAL	LENGTH	WIDTH	DEPTH	FOUNDATION SHAPE	WEIGHT	POST ASSEMBLY TREATMENT	CUTTING		CONNECT-ION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0		WELDED STUDS	MILD STEEL	< 1	< 1	< .25		< 50	NONE	NONE		NONE	DOWN HAND		NONE
1	HULL FITTINGS	FLUSH OR MINIMUM RAISED	H. S. STEEL	1 < 2	1 < 2	.25 < .5		50 < 100	WIRE BRUSH	FITTING CUTTING		FILLET WELD NON-CONT	VERTICAL		AUTO ASSEMBLY
2	PROPULSION MACHINERY	PREDOMIN-ANTLY PLATE	H. Y. STEEL	2 < 3	2 < 3	.5 < .75		100 < 200	BLAST			FILLET WELD CONTIN-UOUS	OVERHEAD		STICK WELD GRAVITY FEED
3	ELECTRICAL	PREDOMIN-ANTLY SECTION	ALUMINUM	3 < 4	3 < 4	.75 < 1		200 < 500	PRIME			BUTT WELD	ROTATE	FLAT PANEL LINE	MIG WELD
4	COMMAND & COMMUNIC-ATIONS	PREDOMIN-ANTLY PIPE OR TUBE		4 < 5	4 < 5	1 < 2		500 < 1000	FINISH COATING			ONE SIDE BUTT WELD	TURN	CURVED PANEL LINE	TIG WELD
5	AUXILIARY MACHINERY	REQUIRING BACK-UP		5 < 10	5 < 10	2 < 3		1000 < 2500	1 + 3			PLUG WELD	0 + 3	PANEL OUTFITT-ING	SUB-ARC WELD
6	OUTFIT	1 + 5		10 < 20	10 < 20	3 < 4		2500 < 5000				FAIR/FILL WELD	0 + 4	MODULE ASSEMBLY	ROBOTIC WELD
7	ARMAMENT	2 + 5		20 < 30	20 < 30	4 < 5		5000 < 10000				BOLT	1 + 3	MODULE OUTFITT-ING	
8		3 + 5		30 < 40	> 30	5 < 7		10000 < 25000				RIVET	1 + 4	SHIP ASSEMBLY	
9		4 + 5		> 40		> 7		> 25000				OTHER	2 + 3	SHIP OUTFITT-ING	

Fig. 6 *(continued)*

1 ST DIGIT -5-AUXILIARY SYSTEMS 2ND DIGIT -1-S. W. SYSTEMS

	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12 TH	13 TH	14 TH	15 TH	16 TH	17 TH
	COMPONENT	TYPE	MATERIAL	DIAMETER	RATING	SCHEDULE	LENGTH	WEIGHT	PRE & POST PROCESSING TREATMENT			CONNECTION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0	PUMPS	L R 90 DEG ELBOW	ASTM A234 GR. B	< 1/4	<125	5	< .25	<5	NONE			BRAZE	DOWN HAND		
1	VALVES	S R 90 DEG ELBOW	ASTM A106 GR 1	1/4 < 1/2	150	10	.25 < .5	5 <10	BLAST			BUTT WELD NO BACKING RING	VERTICAL	.	
2	PIPE	L R 45 DEG ELBOW	ASTM A106 GR 2	1/2 < 3/4	250	20	.5 < .75	10 < 20	WIRE BRUSH			BUTT WELD CONSUMABLE BACKING RING	OVERHEAD		
3	FITTINGS	S R 45 DEG ELBOW	ASTM A181 GR. 1	3/4 < 1	300	40	.75 < 1.	20 < 30	PICKLE			BUTT WELD BACKING RING	ROTATE	SWAGING	
4	HANGERS	180 DEG RETURN	COPPER	1 < 2	400	80	1 < 2	30 < 50	COAT			FLANGE	TURN	PIPE ASSEMBLY FABRICAT-ION	
5	SLEEVES	TEE	BRONZE MIL-F 1183	2 < 3	600	120	2 < 3	50 <100	GALVANIZE			SOCKET	0 • 3	UNIT INSTALAT-ION	
6	INSULATION	CROSSES	CU-NI	3 < 6	900	160	3 < 4	100 <200	1 • 4			SCREWED	0 • 4	PANEL OUTFITT-ING	AUTO FLANGE WELDER
7	HEAT EXCHANGERS	CLEAN OUT	P V C	6 <12	1500		4 < 5	200 <300	2 • 4			VAN STONE	1 • 3	MODULE OUTFITT-ING	MANUAL WELDING
8	FILTERS	REDUCER	G R P	12 <18	2500		5 < 6	300 <600	3 • 5			DRESSER COUPLING	1 • 4	SHIP OUTFITT-ING	ORBITAL WELDER
9	MANIFOLD	CAP		>18	> 2500		> 6	>600					2 • 3		

Fig. 6 (continued)

1 ST DIGIT -5-AUXILIARY SYSTEMS 2ND DIGIT -1-S. W. SYSTEMS

	3RD	4TH	5TH	6TH	7TH	8TH	9TH	10TH	11 TH	12TH	13TH	14TH	15TH	16TH	17TH
	COMPONENT	TYPE	MATERIAL	DIAMETER	RATING	SCHEDULE	LENGTH	WEIGHT	PRE & POST PROCESSING TREATMENT	CUTTING	FORMING	CONNECTION TYPE	WORK POSITION	WORK STATION	EQUIPMENT USED
0	PUMPS	SINGLE PIPE	ASTM A106 GR. A	< 1/4	<125	5	< .25	<50	NONE	NONE	NONE	BRAZE	DOWN HAND	CUTTING	MANUAL CUT
1	VALVES	PIPE WITH BRANCHES	MIL-T 20157C	1/4 < 1/2	150	10	.25 < .5	50 <100	BLAST	SAW	BEND	BUTT WELD NO BACKING RING	VERTICAL	BENDING	AUTO CUT
2	PIPE	SINGLE BEND PIPE	CRES ASTM A312-63 GR.321	1/2 < 3/4	250	20	.5 < .75	100 < 200	WIRE BRUSH	BURN	SWAGE	BUTT WELD CONSUMABLE BACKING RING	OVERHEAD	PULLING	MANUAL BEND
3	FITTINGS	MULTI BEND PIPE	COPPER MIL-T 24107A	3/4 < 1	300	40	.75 < 1.	200 < 300	PICKLE	DISC	PULL "T"	BUTT WELD BACKING RING	ROTATE	SWAGING	N/C BEND
4	HANGERS	0 • 2	COPPER ASTM B280-63	1 < 2	400	80	1 < 2	300 < 500	COAT	BEVELER		FLANGE	TURN	PIPE ASSEMBLY FABRICAT-ION	SWAGING MACHINE
5	SLEEVES	0 • 3	RED BRASS MIL-T 20168B	2 < 3	600	120	2 < 3	500 <1000	GALVANIZE	1 • 4		SOCKET	0 • 3	UNIT INSTALAT-ION	"T" PULL MACINE
6	INSULATION	1 • 2	CU-NI MIL-T 16420	3 < 6	900	160	3 < 5	1000 <2000	1 • 4	3 • 4		SCREWED	0 • 4	PANEL OUTFITT-ING	AUTO FLANGE WELDER
7	HEAT EXCHANGERS	1 • 3	PVC	6 <12	1500		5 < 10	2000 <3000	2 • 4			VAN	1 • 3	MODULE OUTFITT-ING	MANUAL WELDING
8	FILTERS	PIPE ASSEMBLY	GRP	12 <18	2500		10 < 20	3000 <5000	3 • 5			DRESSER COUPLING	1 • 4	SHIP OUTFITT-ING	ORBITAL WELDER
9	MANIFOLD			>18	> 2500		> 20	>5000					2 • 3		

Fig. 6 (continued)

The classification and coding system described was originally developed for the U.S. Navy first digit breakdown, but it is obvious that this is not in strict accordance with the principles of group technology. For example, plate can be used in many of the systems, as can pipe. However, the intent was to develop an overall system that could be used for group technology. In keeping with the approach proposed for design and engineering for ship production, the first digit of the described system could be replaced by a classification that relates to hull, deckhouse, and machinery space, as shown in Fig. 7.

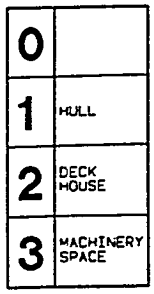


Fig. 7 Optional zero digit for zone design and construction

Group technology and classification and coding systems are of no benefit unless they can be applied to existing shipbuilding practices so that they can be improved. The previously mentioned shipbuilding examples indicate some of the ways, but a shipyard must have a clear goal to achieve before applying any part of group technology. The goal should be clearly documented, and a review of possible methods to achieve it should be made [21]. If group technology is selected as the best method, it is probable that better definition of the current status will be required, and that is where classification and coding is firat applied. Once the classification and coding system is decided, it is necessary to collect data such as number of components routed through Shop A. A data-collection system is necessary, and the use of d processing equipment is probable. An essential part of data-collection system is the data-collection format. Re ences [9], [10], and [12] describe such formata, and Fi shows a typical format. Collected data can be analyse provide the required information, such as number of v connections per component prior to assembly into a mo or the through-put of steel in a particular shop. The in mation provided by the analysis may be used to reduce c ponent handling by relocating work stations, including cessing machines and equipment.

A group-technology analysis could be used to detern the number of similar component designs, allowing th lection of the best and reduction in variety. Once this is complished, every component design requirement ca checked at concept stage to see if an existing design meet the requirement. This is conceptually shown in Fi

As another example, the author recently developed a s material list and, by using claasification and coding (C & techniques, was able to do so quickly and in a fraction o normal number of pages. Stock material lists usually items one by one and line by line for each item; A m code for group listings is normally used, and the new lis also uses a major group code. However, within each m group, the difference is significant. Figure 10 shows a p from a typical stock material list for pipe fittings. The could have over 500 pages of similar data. It can be that there is considerable data duplication, thus requi many pages. Figure 11 is the total list for the correspon major group. The total pipe group of the traditional list 205 pages, whereas the C & C listing used only 18 pa Thus considerable time saving for preparation and u possible with the C & C approach. The use of the C stock material list should be obvious, but for complete the following examples are given:

. threaded coupling, 1/2-in., malleable iron, galvanized, 150# —53301

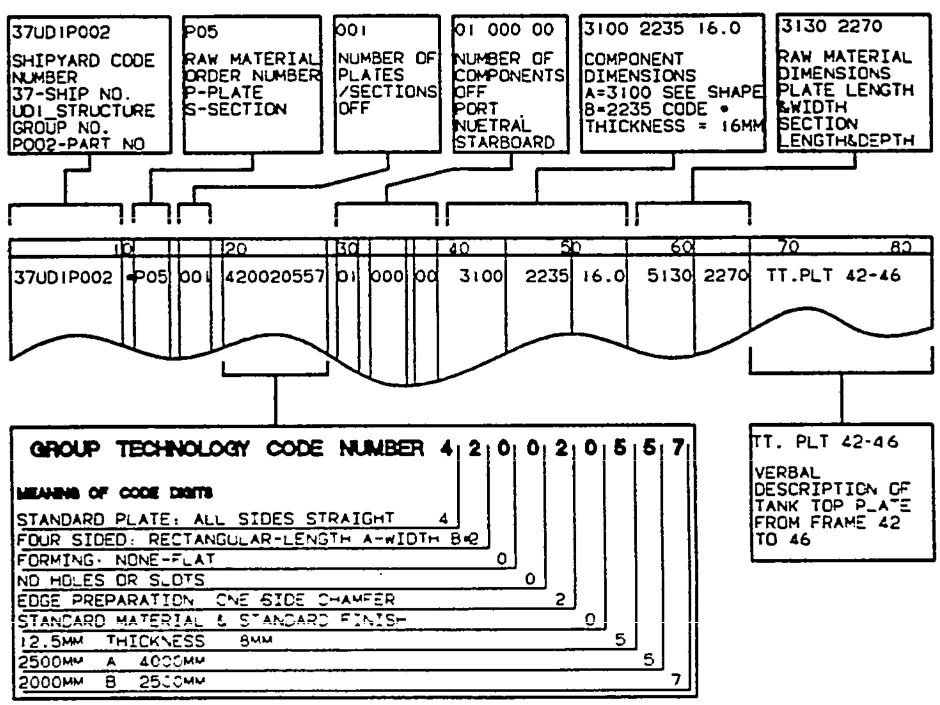


Fig. 8 Typical component information card using group technology

. 3/8 times 3 1/2 in. nipple, Schedule 40, black -53262405

—53266600

One disadvantage with the C & C approach is that it is possible to come up with a number which is meaningless. Therefore, it is essential that the requesting system have a built-in editing capability to identify incorrect coding.

Another example could be to determine the moat producible design of double bottom structure from the following optiona:

- Transverse-all plate floors
- Transverse-combined plate and open floors
- Longitudinal-maximum spacing with struts
- Longitudinal-maximum spacing without struts

A typical hold length would be selected and the structural components coded for product design and processing. Then the following data could be extracted for each option and compared

1. Number of parts
2. Number of unique parts
3. Number of each unique part
4. Number of plate parts
5. Number of parts cut from sections
6. Number of plates formed
7. Number of sections formed
8. Number of process steps for each pert
9. Process flow quantities

By adding a few additional data items to the data collection forms, it would be possible to extract

- joint weld length and
- weight.

A further example is the determination of the number of different section sizes to be used for a particular design. The various minimum scantling sizes as required to meet the classification society rules could be determined, coded, collected, and sorted. Suitable size ranges then would be obVious.

For a shipyard utilizing both contour- and flame-planing burning machines, the designer could code all plates and determine the machine type demand and make changes if they were not in balance. Use of cut plate with flanged or fabricated face plate instead of formed shapes is another necessary comparison where group technology can be used to advantage.

The concept of advanced outfitting can be analyzed by applying group technology techniques as can "emotional" items such as welded pipe joints versus flanged pipe joints. Existing design practice can be analyzed for required processing and, thus, work content, as can the impact of proposed improvements.

However, the ultimate benefit from the use of group technology in design for ship production is that if all interim products are coded it will be possible to utilize CAPP and thus eliminate the errors and inefficiency of manual process planning.

In summary, the application of group technology to shipbuilding provides an opportunity to develop better methods and techniques for the design and construction of ships. The notable benefits include

- Reduction in number of engineering drawings,
- Reduction in new design,
- Company standardization,
- Reduction in design and engineering time and man hours,
- Improved quality,
- Better utilization of facilities,
- Identification and elimination of high work content products and processes,
- Simplified and automated planning,

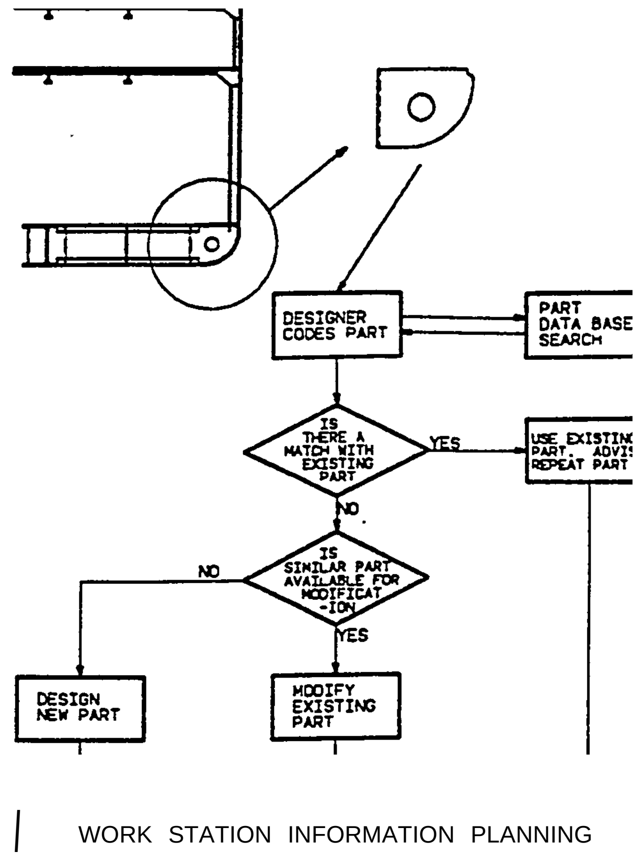


Fig. 9 Group technology in design

- Simplified scheduling and production control,
- Simplifed material flow system and control, and
- Improved productivity.

Acknowledgments

The author would like to acknowledge with thanks t support and encouragement of his colleagues and the T coma Boatbuilding Company to present this paper. Ho ever, the ideas described and the views expressed herein a solely his and do not necessarily reflect those of any as ciate or TBC. Further, thanks are given to Rofessor How Bunch, Chairman of the Education Panel (SP-9) for perm sion to present this paper which is based on a report p pared by the author for the panel, "Engineering for Sl Production."

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(References continued on page 50)

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                    STOCK CODED MATERIAL LIST                                                   PAGE
D E S C R I P T I O N                                                                           117
                                                  REL
  CTGY                                            POINT  U/M  FSN             QSN

COUPLING, (HALF), SOC/WELD, 3000LB, SCH-80,  STL     ASTM A234, GR. WPB    LVL.3
  ALLC  1/4 IN                                                           9-14-07041
  ALLC  3/8 IN                                                           9-14-07042
  ALLC  1/2 IN                                                           9-14-07043
  ALLC  3/4 IN                                                           9-14-07044
  ALLC  1 IN                                                             9-14-07045
  ALLC  1-1/4 IN                                                         9-14-07046   5 WKS
  ALLC  1-1/2 IN                                                         9-14-07047
  ALLC  2 IN                                                             9-14-07048
  ALLC  2-1/2 IN                                                         9-14-07049
  ALLC  3 IN                                                             9-14-07050

COUPLING, SOC-WELD, 2000LB OR 3000LB(SCH-40) CHROME MOLY STL    ASTM A234 GR-WP11 & ASA B16.11  LVL-2
  OBSC  1/4 IN                                                           9-14-07082
  OBSC  3/8 IN                                                           9-14-07083
  OBSC  1/2 IN                                                           9-14-07084
  OBSC  3/4 IN                                                           9-14-07085
  OBSC  1 IN                                                             9-14-07086   8 WKS
  OBSC  1-1/4 IN                                                         9-14-07087
  OBSC  1-1/2 IN                                                         9-14-07088
  OBSC  2 IN                                                             9-14-07089

COUPLING, SCALE FREE, MALE & FEMALE, STANDARD WEIGHT, CARBON STEEL    ASTM A105, GR 1   LAVISH
  OBSC  2 IN                                                             9-14-07097

COUPLING, HALF, THREADED, 3000LB, STEEL   ASTM A105, GR 2    LVL 3
  ALLC  1/4 IN.                                                          9-14-07140
  ALLC  3/8 IN.                                                          9-14-07141
  ALLC  1/2 IN.                                                          9-14-07142
  ALLC  3/4 IN.                                                          9-14-07143
  ALLC  1 IN.                                                            9-14-07144
  ALLC  1-1/4 IN.                                                        9-14-07145
  ALLC  1-1/2 IN.                                                        9-14-07146
  ALLC  2 IN.                                                            9-14-07147
  ALLC  2-1/2 IN.                                                        9-14-07148   5 WKS
  ALLC  3 IN.                                                            9-14-07149

COUPLING, THREADED, 300LB-WSP, MALLEABLE IRON, GALV   ASTM A197 & ASA B16.3    COMML
  ALLC  1/2 IN                                                           9-14-07158
  ALLC  3/4 IN                                                           9-14-07159
  ALLC  1 IN                                                             9-14-07160
  ALLC  1-1/4 IN                                                         9-14-07161
  ALLC  1-1/2 IN                                                         9-14-07162
  ALLC  2 IN                                                             9-14-07163

COUPLING, BANDED, THREAD, 150LB, MALLEABLE IRON     ASTM A197 & ASA B16.3     LVL 3
  ALLC  1/4                                                              9-14-07170
  ALLC  3/8                                                              9-14-07171
  ALLC  1/2                                                              9-14-07172
  ALLC  3/4                                                              9-14-07173
  ALLC  1                                                                9-14-07175
  ALLC  1-1/4                                                            9-14-07176   3 WKS
  ALLC  1-1/2                                                            9-14-07177
  ALLC  2                                                                9-14-07179
  ALLC  2-1/2                                                            9-14-07180
  ALLC  3                                                                9-14-07182
  ALLC  4                                                                9-14-07184

COUPLING, BANDED, THREADED, 150LB, GALV MALLEABLE IRON    ASTM A197 & ASA B16.3    LVL 3
  ALLC  1/4                                                              9-14-07190
  ALLC  3/8                                                              9-14-07191
  ALLC  1/2                                                              9-14-07192
  ALLC  3/4                                                              9-14-07193
  ALLC  1                                                                9-14-07194   4 WKS
  ALLC  1-1/4                                                            9-14-07195
  ALLC  1-1/2                                                            9-14-07196
  ALLC  2                                                                9-14-07197
  ALLC  2-1/2                                                            9-14-07198
  ALLC  3                                                                9-14-07199

COUPLING, SOC-WELD, 3000LB, CRES    ASTM A182, GR F304    LVL 3
  ALLC  1/4                                                              9-14-07210
  ALLC  3/8                                                              9-14-07211
  ALLC  1/2                                                              9-14-07212   5 WKS
  ALLC  3/4                                                              9-14-07213
  ALLC  1                                                                9-14-07214
```

Fig. 10 Typical stock material list format

STOCK LIST

Rev.	: A
Issue Date	: 617185
Page No.	: 15

1st Digit	6roup Code	5	FLUID DISTSIBUTION SYSTEMS
2nd Digit	Corponent Code	3	STRAIGHT FITTINGS

CODE	3rd Digit Size	4th Digit Additional Size	5th Digit Material	6th Digit Type	7th Digit Connection	8th Digit Rating	RE HARKS
0	1/8	Not Used	Malleable Iron Black A5TN A197	Coupling	Not Used	Not Used	
1	1/4	1	Malleable Iron Galv ASTM A197	Cap	Socket Weld	125#	
2	3/8	1-1/2	Steel Black ASTm A234	Union	Butt Weld	150#	
3	1/2	2	Steel Galvanized ASTM A344	Plug	Threaded	300#	
4	3/4	2-1/2	Cres ASTM 182	Nipple	Flared	3000#	
5	1	3	Bronze ASTM B61		Brazed	SCH 40	
6	1-1/4	3-1/2	Copper ASTM B75	SEE	Solder	SCH 80	
7	1-1/2	4	CU NI	PAGE NO.			
8	2	5	PVC ASTM D2464-7	16			
9	2-1/2	6	Aluminum ASTM B-26				

STOCK LIST

Rev.	: A
Issue Date:	6/7/85
Page No	: 16

1st Digit	Group Code	5	FLUID DISTRIBUTION SYSTEMS
2nd Digit	Component Code	3	STRAIGHT FITTINGS

CODE	3rd Digit Size	4th Digit Additional Size	5th Digit Material	6th Digit Type	7th Digit Connection	8th Digit Rating	REMARKS
0	1/8	Not Used	Malleable Iron Black ASTM A197		Not Used	Not Used	
1	1/4	1/8	Malleable Iron Galv ASTM A197	SEE	Socket Weld	125#	
2	3/8	1/4	Steel Black ASTM A234	PAGE NO.	Butt Weld	150#	
3	1/2	3/8	Steel Galvanized ASTM A344	15	Threaded	300#	
4	3/4	1/2	Cres ASTM 182		Flared	3000#	
5	[illegible]	3/4	Bronze ASTM B61	Hex Reducing Bushing	Brazed	SCH 40	
6	1-1/4	1	Copper ASTM B75	Adapter Male	Solder	SCH 80	
7	1-1/2	1-1/4	CU NI	Adapter Female			
8	[illegible]	1-1/2	PVC ASTM D2464-7	Connection Male			
9	2-1/2	2	Aluminum ASTM B-26	Connection Female			

Fig. 11 C & C-based stock material list

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NATIONAL SHIPBUILDING PROGRAM

SHIPBUILDING POLICY AND BUILD STRATEGY

DESIGN FOR PRODUCTION INTEGRATION

DESCRIPTION OF "AS IS" UTILIZATION OF BUILD STRATEGY APPROACH IN U.S. SHIPBUILDING

THE TERM BUILD STRATEGY HAS DIFFERENT MEANING IN DIFFERENT U.S. SHIPYARDS

MANY SHIPYARDS ONLY COVER PRODUCTION STAGES IN THEIR BUILD STRATEGY

THE EXTENT OF CURRENT COVERAGE IN U.S. SHIPYARDS IS WELL BELOW THAT RECOMMENDED IN THE NSRP REPORT "**BUILD STRATEGY DEVELOPMENT**' HOWEVER, MOST SAID THAT THEY WERE EXPANDING THEIR USEAGE TOWARD THE REPORT RECOMMENDATIONS AS THEIR PROCESSES ARE DEVELOPED AND DEFINED

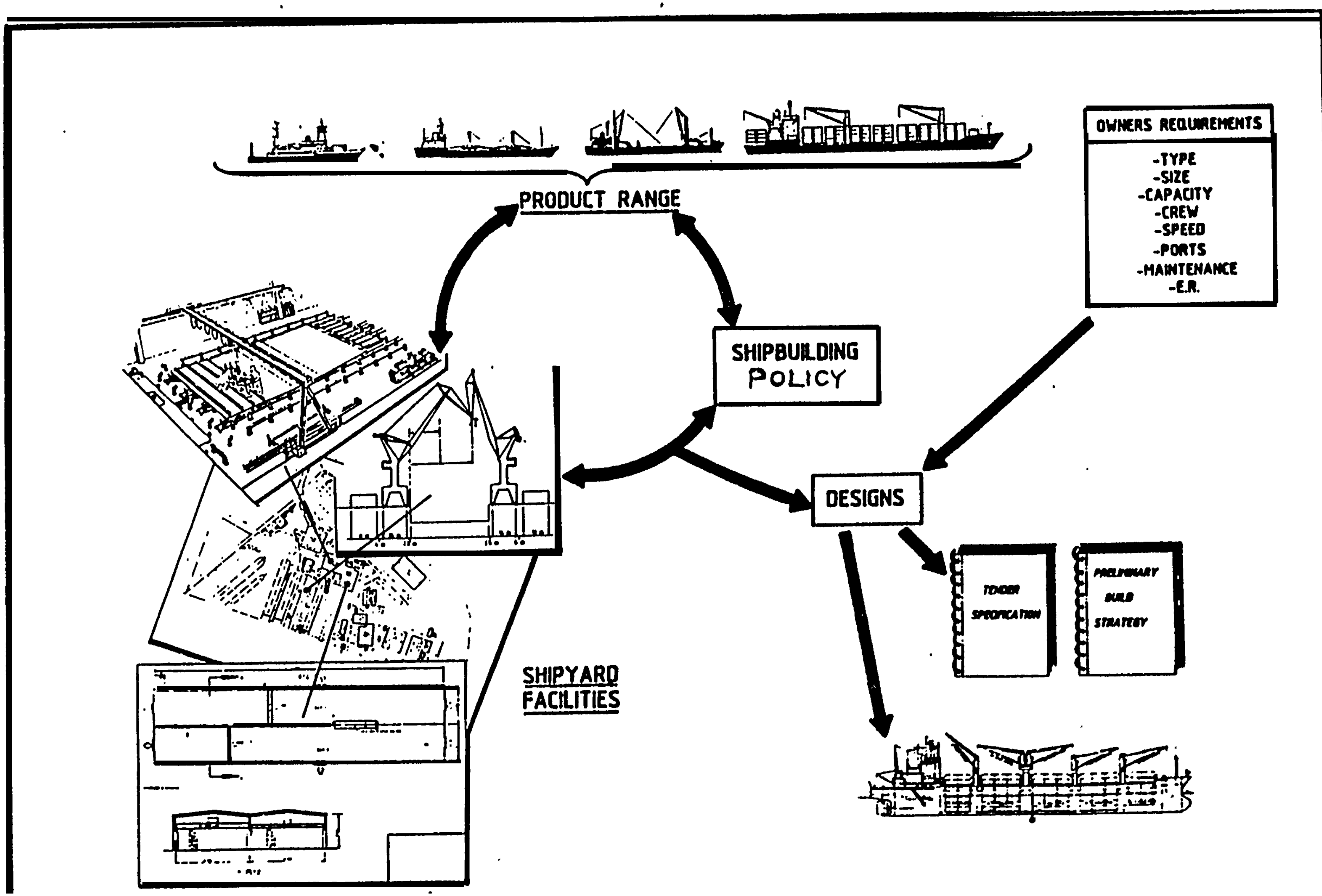
DESCRIPTION OF "AS IS" UTILIZATION OF BUILD STRATEGY APPROACH IN U.S. SHIPBUILDING (CONTINUED)

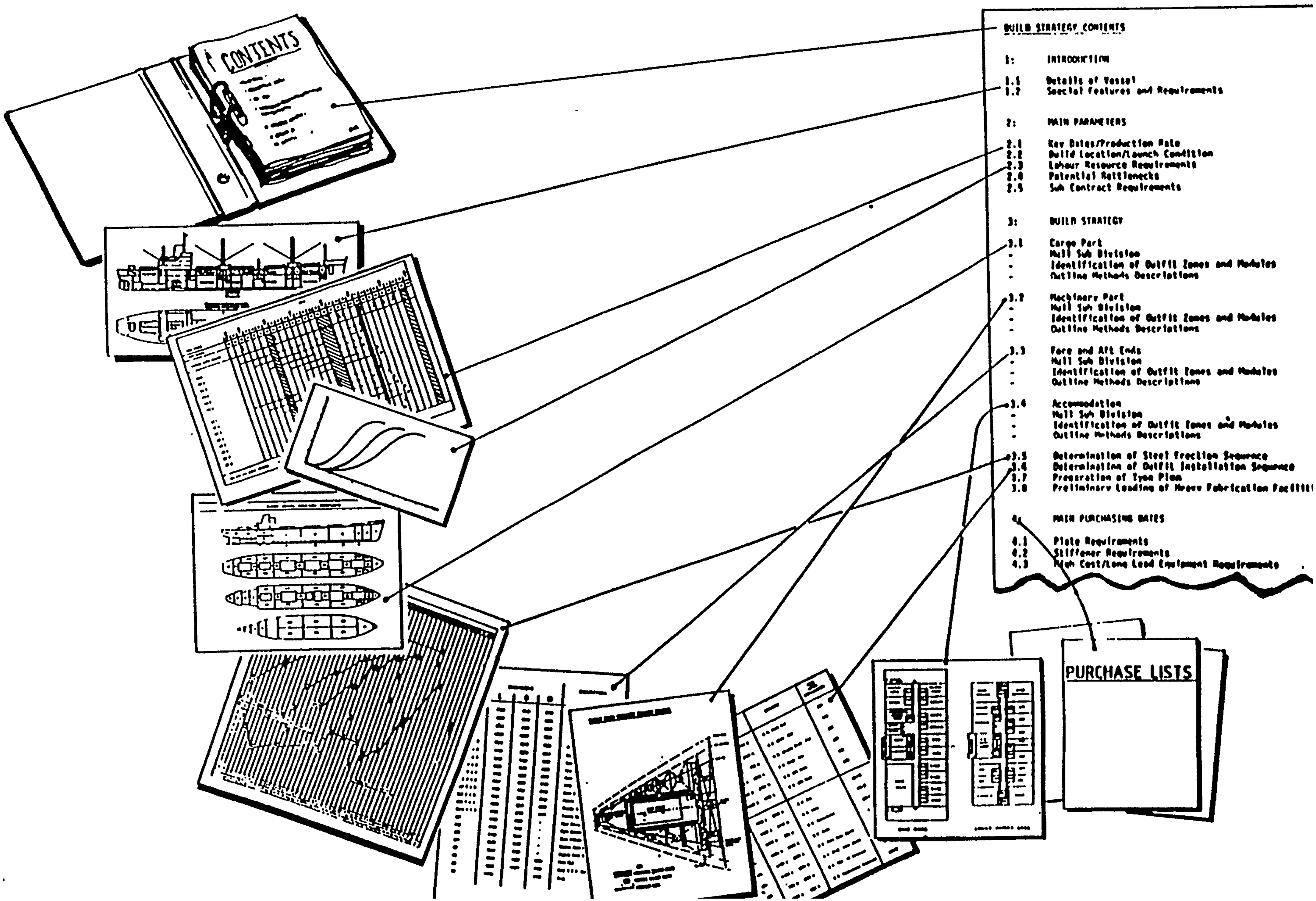
VERY FEW U.S. SHIPBUILDERS FOLLOW THE

BUSINESS PLAN (FOR SHIPYARD)
↓
SHIPBUILDING POLICY (FOR SHIPYARD)
↓
SHIP DEFINITION (FOR SHIPS IN PRODUCT RANGE
↓
BUILD STRATEGY (FOR EACH SHIP IN PRODUCT RANGE)

BUILD STRATEGY USED TO ITS FULLEST EXTENT IS AN EFFECTIVE COLLABORATION TOOL

BUID STRATEGY CAN BE USED AS THE "CONTROL" DOCUMENT FOR A CONCURRENT ENGINEERING APPROACH


PRODUCT RANGE
OWNERS REQUIREMENTS
-TYPE
-SIZE
-CAPACITY
-CREW
-SPEED
-PORTS
-MAINTENANCE
-E.R.
SHIPBUILDING POLICY
DESIGNS
TENDER SPECIFICATION
PRELIMINARY BUILD STRATEGY
SHIPYARD FACILITIES


CONTENTS
BUILD STRATEGY CONTENTS
1: INTRODUCTION
1.1 Details of Vessel
1.2 Special Features and Requirements
2: MAIN PARAMETERS
2.1 Key Dates/Production Rate
2.2 Build Location/Launch Condition
2.3 Labour Resource Requirements
2.4 Potential Bottlenecks
2.5 Sub Contract Requirements
3: BUILD STRATEGY
3.1 Cargo Part
- Hull Sub Division
- Identification of Outfit Zones and Modules
- Outline Methods Descriptions
3.2 Machinery Part
- Hull Sub Division
- Identification of Outfit Zones and Modules
- Outline Methods Descriptions
3.3 Fore and Aft Ends
- Hull Sub Division
- Identification of Outfit Zones and Modules
- Outline Methods Descriptions
3.4 Accommodation
- Hull Sub Division
- Identification of Outfit Zones and Modules
- Outline Methods Descriptions
3.5 Determination of Steel Erection Sequence
3.6 Determination of Outfit Installation Sequence
3.7 Preparation of Type Plan
3.8 Preliminary Loading of Heavy Fabrication Faciliti
4: MAIN PURCHASING DATES
4.1 Plate Requirements
4.2 Stiffener Requirements
4.3 High Cost/Long Lead Equipment Requirements
PURCHASE LISTS

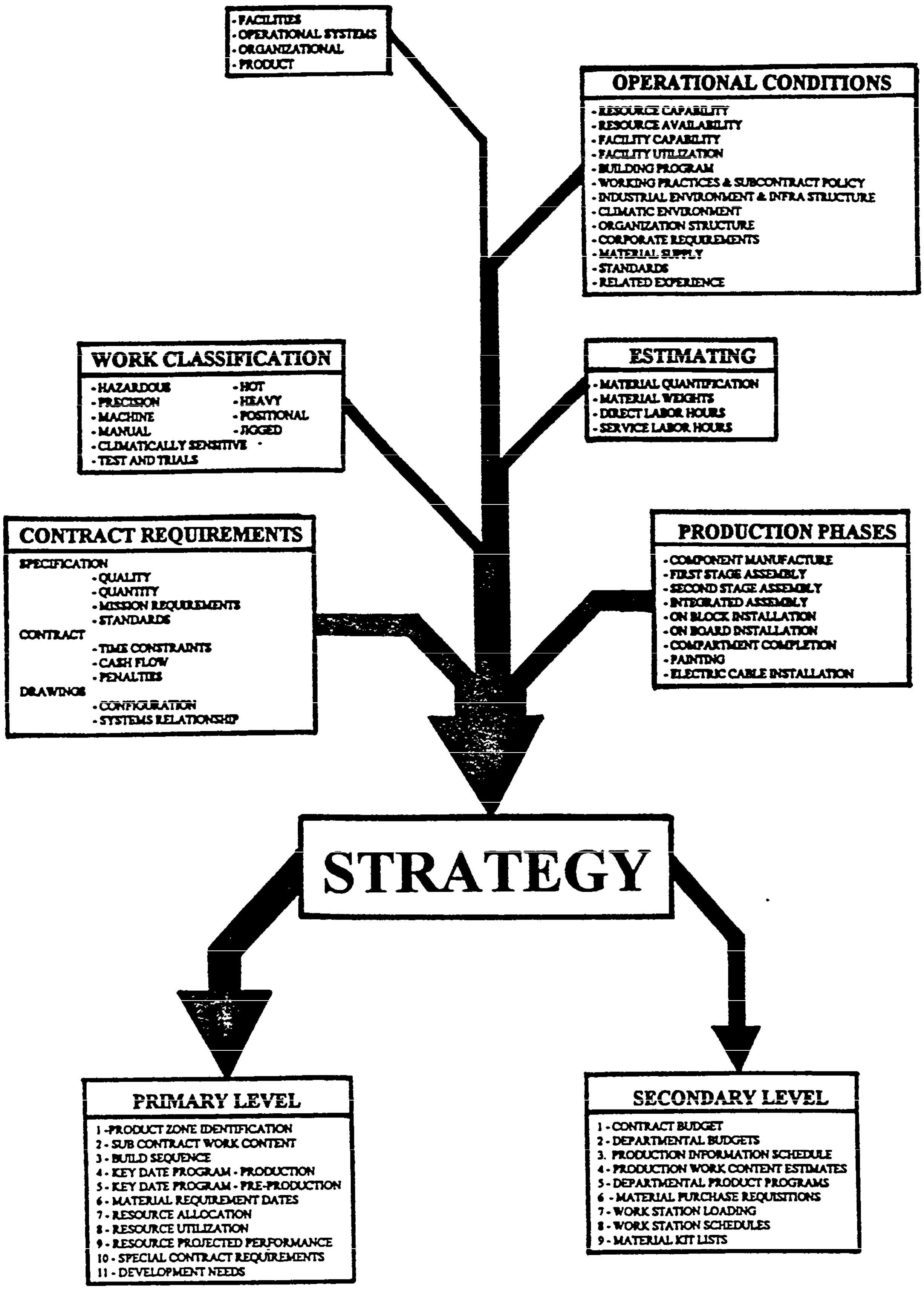


FIGURE 1.2.2 - BUILD STRATEGY PROCESS

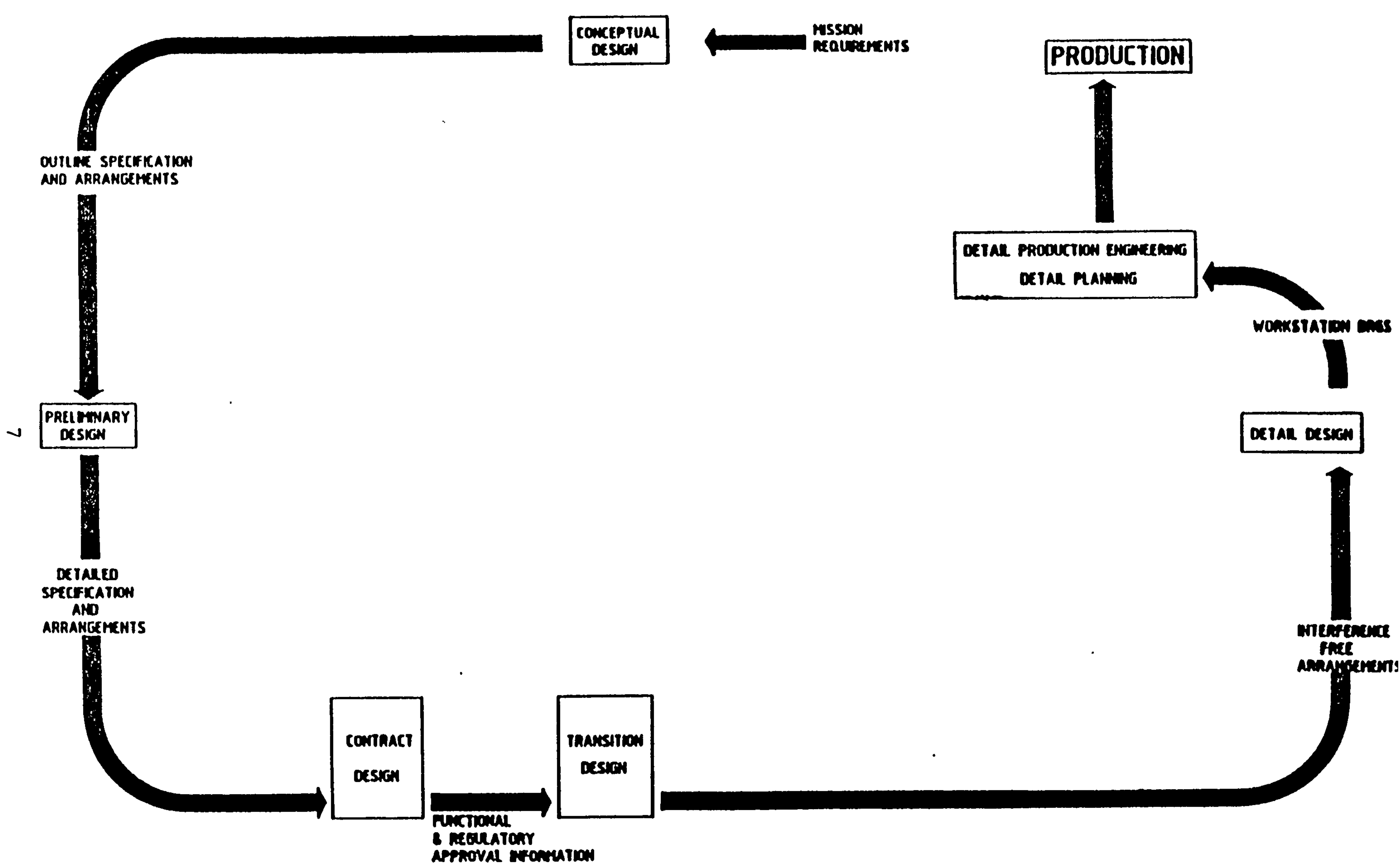
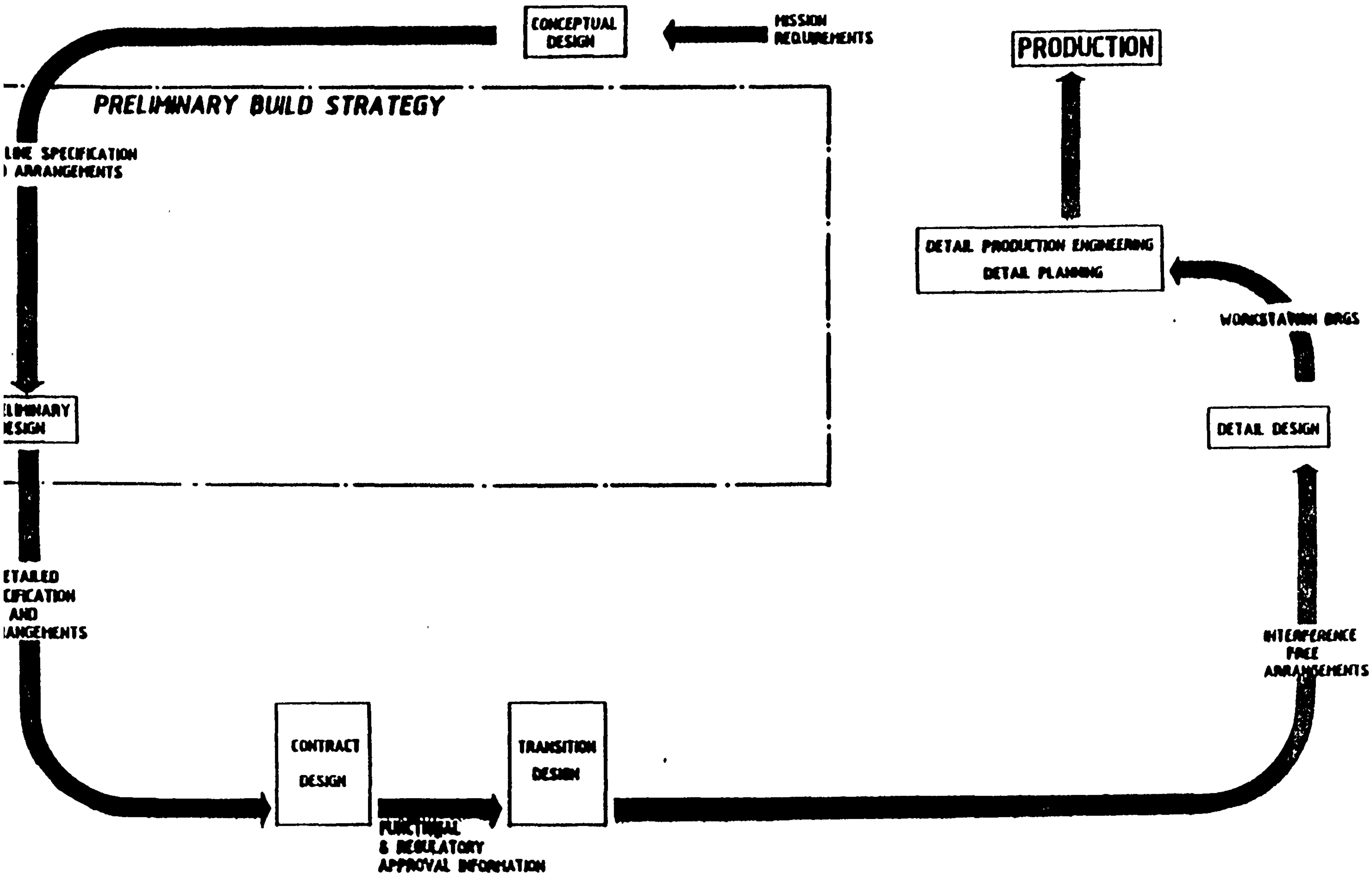


FIGURE 1.2.3 - BUILD STRATEGY ROUTE MAP


CONCEPTUAL DESIGN
MISSION REQUIREMENTS
PRODUCTION
PRELIMINARY BUILD STRATEGY
LINE SPECIFICATION
ARRANGEMENTS
ELIMINARY
DESIGN
DETAIL PRODUCTION ENGINEERING
DETAIL PLANNING
DETAIL DESIGN
ETAILED
CIFICATION
AND
ANGEMENTS
INTERFERENCE
FREE
ARRANGEMENTS
CONTRACT
DESIGN
TRANSITION
DESIGN
FUNCTIONAL
& REGULATORY
APPROVAL INFORMATION

8

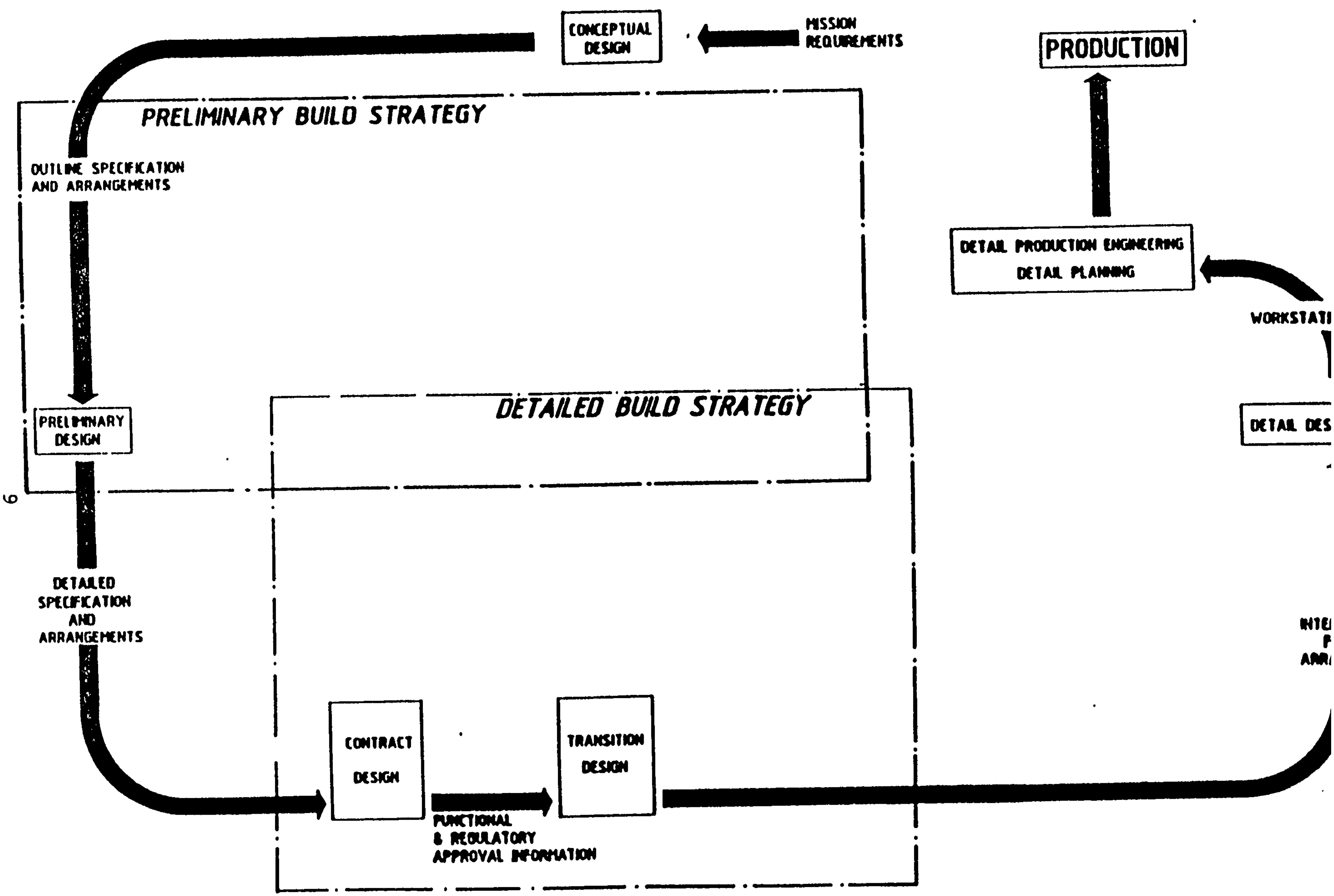
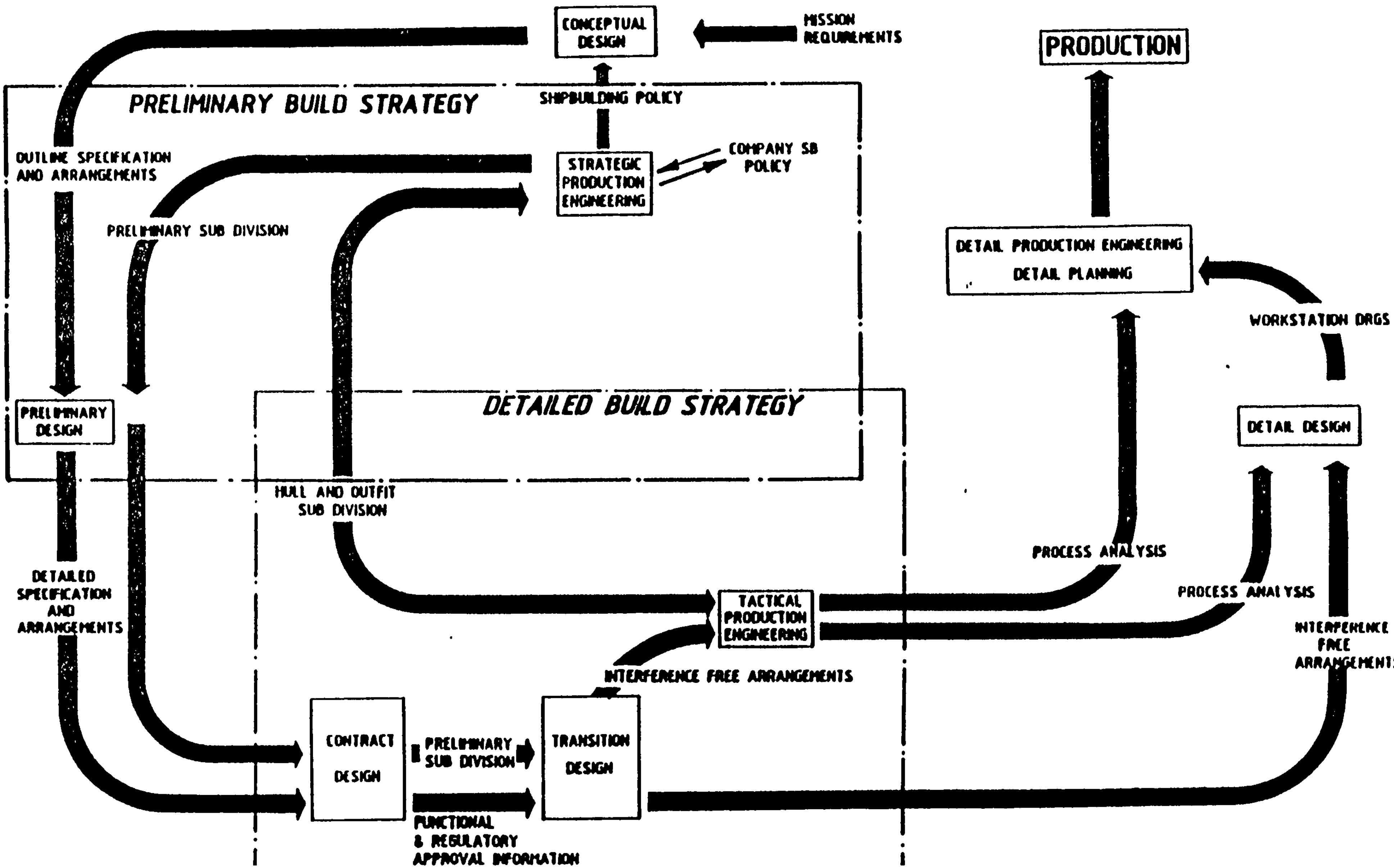


FIGURE 1.2.3 (continued) - BUILD STRATEGY ROUTE MAP



CONCEPTUAL DESIGN
MISSION REQUIREMENTS
PRODUCTION
PRELIMINARY BUILD STRATEGY
SHIPBUILDING POLICY
OUTLINE SPECIFICATION AND ARRANGEMENTS
STRATEGIC PRODUCTION ENGINEERING
COMPANY SB POLICY
PRELIMINARY SUB DIVISION
DETAIL PRODUCTION ENGINEERING
DETAIL PLANNING
WORKSTATION DRGS
PRELIMINARY DESIGN
DETAILED BUILD STRATEGY
DETAIL DESIGN
HULL AND OUTFIT SUB DIVISION
PROCESS ANALYSIS
DETAILED SPECIFICATION AND ARRANGEMENTS
TACTICAL PRODUCTION ENGINEERING
PROCESS ANALYSIS
INTERFERENCE FREE ARRANGEMENTS
INTERFERENCE FREE ARRANGEMENTS
CONTRACT DESIGN
PRELIMINARY SUB DIVISION
TRANSITION DESIGN
FUNCTIONAL & REGULATORY APPROVAL INFORMATION

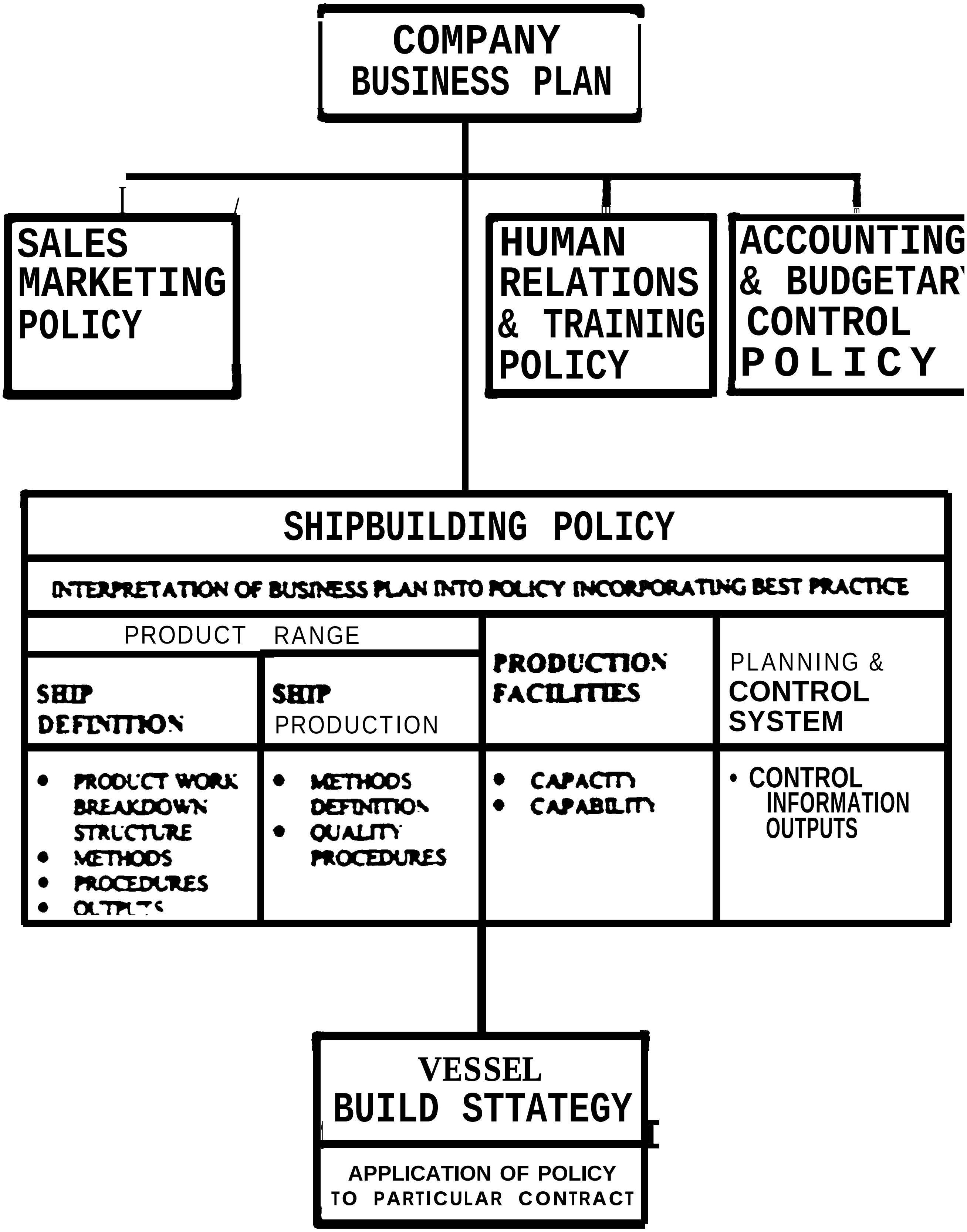


Figure 1- Build Strategy and Shipbuilding Policy

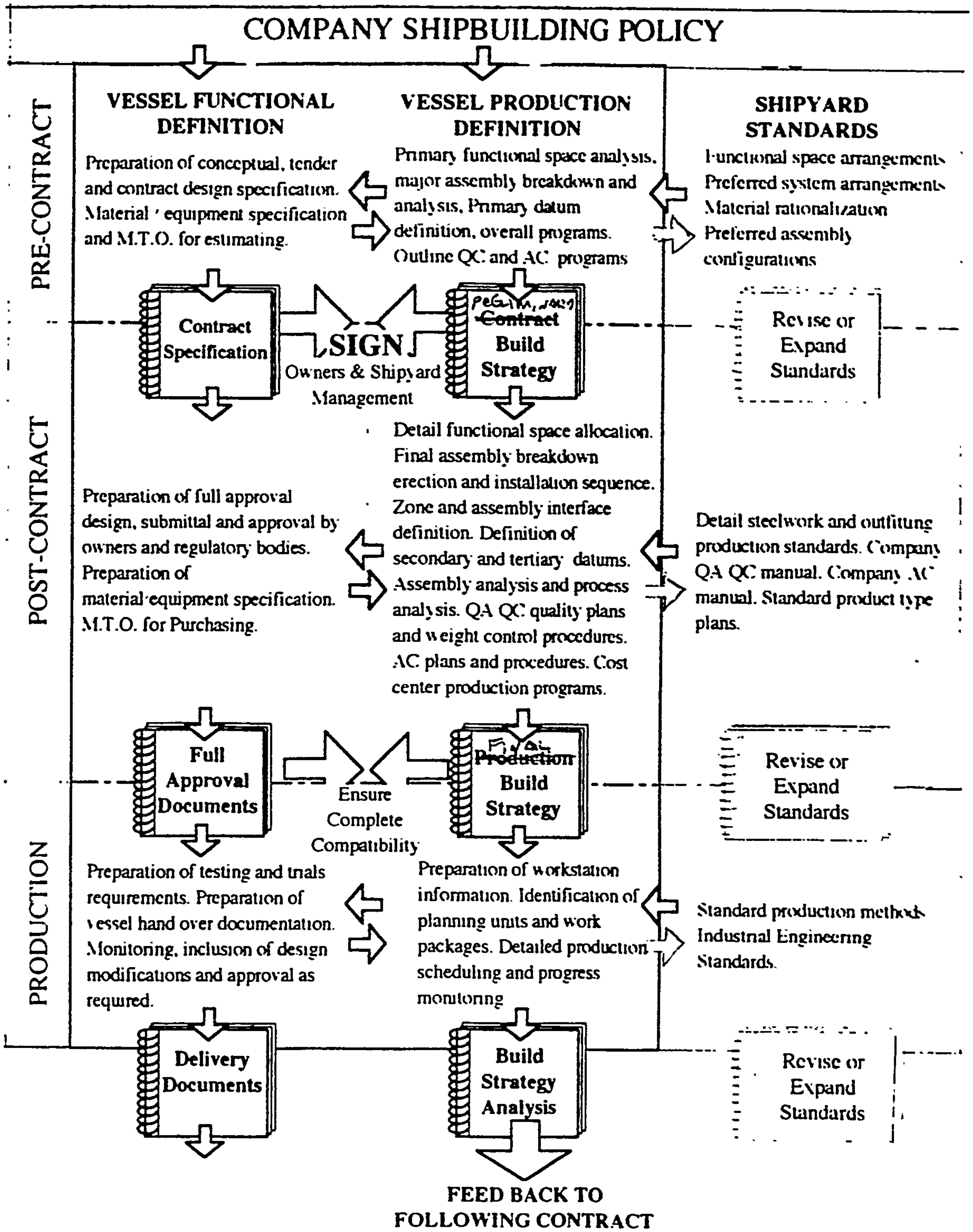


Figure 13
Outline of Ship Design Strategy

THE SOCIEIY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
601 PAVONIA AVENUE, JERSEY CITY, NJ 0730S
Paper prepared at the1985 Sho Production Symposurn
Westen Hotel Washington, January 25-27, 1995 I

Build Strategy Development

John Clark (V), A & P Appledore International Ltd., U. K., and Thomas Lamb (FL), Textron Marine & Land Systems, U.S.A.

ABSTRACT

The 1985 NSRP "Design For Production Manual (SP-4, 1986) describes the use of a Build strategy as a basis for improved shipbuilding performance through front end involvement of all department and better comummication. A number of U.S. shipbuilders are known to have used the approach However, the extent of its use and the experience of the users was unknow

To remedy this situation the SP-4 Panel conceived a project to determine; (1) how widely the Build Strategy approach was known and used by U.S. shipbuilders, and (2) a suitable Build Strategy framework with examples of its use for two typical ship types.

This paper sumarizes the performance Of the project and briefly describes the findings of the U.S. and foreign shipyard surveys and visits, the rquired prerequisites for use of a Build Strategy and benefits from its use. It also includes the contents list for the proposed Build Strategy framework

INTRODUCTION

All shipbuilders plan how they will build their ships. The plan may be only in someone's head or a detailed and documented process involving many people. often different departments prepare independent plans which are then integrated by a "Master Plan/Schedule".

A Build Strategy is much more than the normal planning and scheduling and a description of how the Production Department will build the ship.

Many shipbuilders use the term "Build Strategy" for what is only their Production Plan In terms of this project this is incorrect. The term "Build Strategy", as used throughout this paper has a special, specific meaning. It is also recognized that some shipbuilders have a process very similar to the Build Strategy approach but do not call it such.

What is the meaning by the term Build Strategy for this project? Before specifying the aims of a Build Strategy are briefly discussed.

It

- applies a company's overall shipbuilding policy to a contract,
- provides a process for ensuring that design development takes full account of production requirements,
- systematically introduces production engineering principles that reduce ship work content and cycle time
- identifies interim products and creates product-oriented approach to engineering and planning of the ship,
- determines resource and skill requirements and overal facility loading,
- identifies shortfalls in capacity in terms of facilities, manpower and@
- creates parameters for programming and detail planning of engineering procurement and production activities,
- provides the basis on which any eventual production of the product may be organized including procurement dates for "long lead" material items,
- ensures all departments contribute to the strategy.
- identifies and resolves problems before work on the contract begins, and
- ensures Communication, cooperation collaboration and consistency between the various technical and production functions.

In summary:

A BUILD STRATEGY IS AN AGREED DESIGN, ENGINEERING, MATERIAL MNAGEMENT, PRODUCTION AND TESTING PLAN, PREPARED BEFORE WORK STARTS, WITH THE AIM OF IDENTIFYING AND INTEGRATING ALL NECESSARY PROCESSES.

BACKGROUND

It was A&P Appledore that conceived and developed the forma Build Strategy approach in the early 1970's. It developed from the ideas and processes generated to support the A & P Appledore associated "Ship Factories" at Sunderland and Appledore. The detailed work breakdowm formalized work sequencing and very short build cycles associated with these ship factories required the communication coordination and cooperation that are inherent in the Build Strategy approach.

British Shipbuilders adopted the Build Strategy approach for all their shipyards (Vaugham 1983)* and A&P Appledore consulting group continued to develop the approach as a service to their clients.

The Build Strategy approach was introduced into the U.S. by A&P Appledore's participation in IREAPS Conferences, as well as through presentations to individual shipbuilders and the SP-4 Panel (Craggs, 1983; A&PA 1983; and A&PA, 1984).

A&P Appledore consulting to NORSHIPCO, Lockheed Shipbuilding Company and Tacoma Boat introduced the use of the Build Strategy approach to U.S. shipbuilding projects. Finally, the Build Strategy approach was described in the DESIGN FOR PRODUCITON Manual, prepared by A&P Appledore for the SP-4 Panel (SP-4,1986).

The concept of the Build Strategy has existed for a number of years, and there has been an ongoing development of the concept in those shipyards which have adopted the Build Strategy approach. During this time, shipyards in Britain, and other countries, have had considerable experience in applying this technology, and it was appropriate to update the original Build Strategy approach in the light of this experience.

It is a known fact,but, unfortunately, a not an often practiced approach, that the performance of any endeavor will be improved by improvements in communications, cooperation and collaboration. A Build Strategy improves all three. It communicates the intended total shipbuilding project to all participants. This communication fosters improved cooperation as everyone is working to the same plan. It improves collaboration by involving most of the stakeholders (interested parties) in its development.

Why was this project necessary? It was perceived by some shipbuilders and the U.S. Navy that the formal documented Build Strategy approach had not been enthusiastically embraced by U.S. shipbuilders.

If the Build Strategy approach is thought to be such a good idea and/or shipbuilding improvement tool, it is surely worthwhile to try to find out if this is the case, and. also to find out why it is not being used by U.S. shipyards.

PREREQUISITES FOR A BUILD STRATEGY

A Build Strategy could be produced as a stand alone document for any ship to be built by a shipyard but it would be a great deal thicker and would take a lot more the Build Strategy effort to produce if certain other documents had not been prepared earlier.

The first of these documents would be the shipyard's Business Plan, which will probably exist in most shipyards. A Business Plan sets out the participation in IREAPS SHIPYARD'S ambitions for a period of years and describesi how the shipyard aims to attain them.

Next a Shipbuilding Policy should be in place. The policy defines the product mix which the shipyard intends to build plus the optimum organization and procedures which will allow it to produce ships efficiently. The Shipbuilding Policy will also include methods for breaking the ships in the product mix into standard interim products by applying a product work Breakdown Structure. Areas in which the interim products will be produced and the tools and procedures to be used will also be defined.

Ideally, a Ship Definition Policy will also exist. This sipecifies the format and content that the engineering information will take in order to support the manner in which the ships will be built.

If any of these documents do not exist, then the information relevant to a particular contract that would have been in them will have tobe produced and included in the Build Strategy.

RELATIONSHIP BETWEEN SHIPBUILDING POLICY AND BUILD STRATEGY

A Shipbuilding Policy is the definition of the optimum organization and build methods required to produce the product mix remained within the company's shipbuilding ambitions as defined in the Business Plan. The Shipbuilding Policy is aimed primarily at design rationalization and standardization, together with the related work organization, to simulate the effect of series construction. This is achieved by the application of group technology and a product work breakdown which leads to the formation of interim product families.

* See REFERENCES

A Shipbuilding Policy is developed from a company's Business Plan, which usually covers a period of five years and includes such topics as

- the product range which the shipyard aims to build,
- shipyard capacity and targeted output,
- targets for costs, and
- pricing policy.

The product range is identified, usually as a result of a market study.

The relationship between a Business Plan, Shipbuilding policy, and Build Strategy is shown in Figure 1.

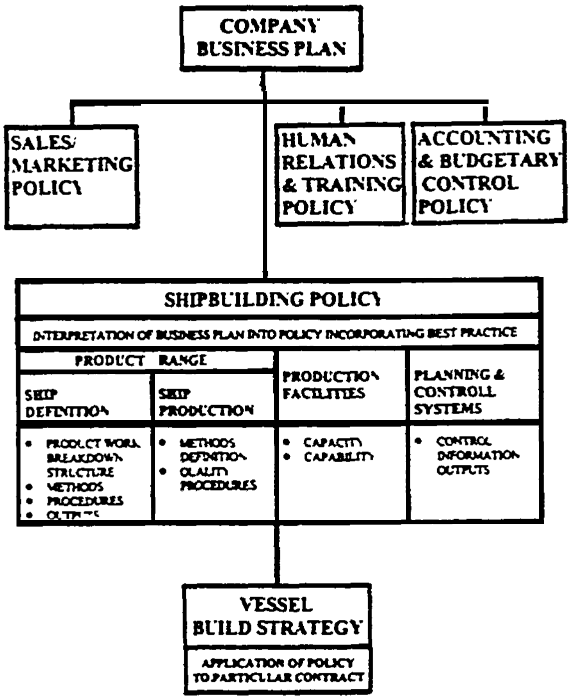


Figure 1- Build Strategy and Shipbuilding Policy

The Business Plan sets a series of targets for the technical and production part of the organization. To meet these targets, a set of decisions is required on:

- facilities development
- productivity targets,
- make, buy or subcontract, and
- technical and production organization.

These form the core of the Shipbuilding Policy. The next level in the hierarchy defines the set of strategies by which this policy is realized, namely the Build Strategy.

In essence, the shipbuilding Policy comprises a set of standards, which can be applied to specific ship contracts. The standards apply at different levels

- Strategic, related to type plans, planning units, interim product types, overall facility dimensions, and so on, applied at the Conceptual and Preliminary Design stages.
- Tactical, related to analysis of planning units, process analysis, standard products and practices, and so on; applied at the Contract and Transition Design stages.
- Deatil, related to work station operations and accuracy tolerances; applied at the Detail Design stage.

Because shipbuilding is dynamic, there needs to be a constant program of product and process development Also, the standards to be applied will change over time with product type, facilities, and technology development.

The shipbuilding policy is therefore consistent but at the same timewill undergo structured process of change, in response to product development, new markets, facilities development, and other variations.

The policy has a hierarchy of levels which allow it to be applied in full at any time to a particular contract.

Therefore, to link the current policy with a future policy, there should be a series of projects for change which are incorporated into an overall action plan to improve productivity. Since facilities are a major element in the policy, a long term development plan should exist which looks to a future policy in that area This will be developed against the background of future business objectives, expressed as a plan covering a number of years.

These concepts are summarized and illustrated in Tables I and II.

Work at the Strategic level provides inputs to

- the conceptual and preliminary design stages,
- contract build strategy,
- facilities development,
- organizational changes, and
- the tactical level of shipbuilding policy.

At the strategic level, a set of documents would be prepared which address the preferred product range. For each vessel type, the documents will include:

- definition of the main planning units,
- development of type plans, showing the sequence of erection, and
- analysis of main interim product types.

TABLE 1
ELEMENTS OF SHIPBUILDING POLICY

POLICY **OVERVIEW**
Policy Based on Business Plan Objectives
Sets Objectives for Lower Levels

CURRENT PRACTICE
Existing Standards
"Last Best" Practice
Procedures to be Applied to Next Contract

PRODUCTIVITY ACTION PLAN
Covers Next Twelve Months
Plans Improvements in Specific Areas
Isa Set of Projects

FUTURE PRACTICE
Developed from Current Practice
Incorporates Outcome of Action Plan
Proceduresto be Applied to Future Contracts

LONG TERM DEVELOPMENT PLAN
Covers Facilities Development
Covers a Five Year Period

TABLE 2
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The strategic level will also address the question of facility capability and capacity.

Documentation on the above will provide input to the conceptual design stage except, of course, in those eases where a design agent is undertaking the design work and the builder has not been identified

Documentation providing input to the preliminary design stage will include

- preferred raw material dimensions,
- maximum steel assembly dimensions,
- maximum steel assembly weights,
- material forming capability, in terms of preferred hull configurations,,
- "standard" preferred outfit assembly sizes, configuration and weights, based on facility capacity/capability, and
- "standard" preferred service routes.

At the tactical level standard interim products and production practices related to the contract and transition design stages, and to the tactical planning level will be developed. All the planning units will be analyzed and broken down into a hierarchy of products.

The policy documents will define preferences with respect to:

- standard interim products,
- Standard product process and methods.
- standard production stages,
- installation practices,
- standard material sizes, and
- standard piece parts.

The capacity and capability of the major shipyard facilities will also be documented.

For the planning units, sub-networks will be developed which define standard times for all operations from installation back to preparation of production information These provide input to the planning function.

At the Detail level the policy provides standards for production operations and for detail design.

The documentation will include:

- Workstation descriptions,
- workstation capacity,
- Worksstation capability,
- design standards,
- accuracy control tolerances,
- welding standards, and
- testing requirements.

Reference to the standards should be made in eontracts, and relevant information made available to the design, planning and production functions.

As with all levels of the shipbuilding policy, the standards are updated over time, in line with product development and technological change.

A ship definition is a detailed description of the procedures to be adopted and the information and format of that information to be produced by each department developing technical information within a The description must ensure that the information produced by each department is in a form suitable for the users of that information

These users include:

- ship owners or their agents,
- shipyard management
- classification societis
- government bodies,
- other technical departments:
  - design and drawing offices.
  - CAD/CAM center,
  - lofting
  - planning

- production engineering
- production control,
- material control,
- estimating
- procurement. and
- production departments

Preferably the ship under consideration would also be of a type which has been identified in the Shipbuilding Policy as one which the shipyard is most suited to build.

The next best scenario would be that the ship being designed was of a type for which a build strategy exists within the shipyard.

BENEFITS OF A BUILD STRATEGY TO U.S. SHIPBUILDERS

If mass production industries such as automobile manufacture, are examined,there is no evidence of the usc of build strategies.

Some shipyards, which have a very limited product variety, in terms of interim and final products, generally speaking also have no need for build strategies, due to their familiarity with the products. if such Shipyards, which are amongst the most productive in the world do not use build strategis then why should the U.S. industry adopt the build strategy approach?

The answer lies in the differences in the commercial environments prevalent and the gearing of operating systems and technologies to the product mix and marketing strategies. In a general sense, the most productive yards have identified market niches, developed suitable standard ship designs, standard interim products and standard build methods. By various means, these yards have been able to secure Sufficient orders to sustain a skillbase which has become familiar with those standards. As the degree of similarity in both interim andfinal products is high, there has been no need to re-examine each vessel to produce detailed build strategies, but many of them do as they find the benefits greatly outweigh the effort.

It is most l.ikely that the U.S. shipbuilding industry's re-entry into major commercial international markets will begin with one-offs or at best very limited series contracts. Furthermore, as many U.S. shipyards believe that it will be most effective to concentrate on complex vessels, the build strategy approach will be a key factor in enabling the yards to obtain maximum benefit from the many advanced technologies. most of which have been made available through the work of the NSRP Ship Production Panels. Also. the Build Strategy approach will ensure that the way they are to be applied is well planned and communicated to all involved.

Most shipyards will have elements of a Build Strategy Document in place. However. without a formalized Build Strategy Document the lines of communication may be too informal and variable for the most effective strategy to be developed.

A well organized shipyard will have designed its facilities around a specific product range and standard production methcds which are supported by a variety of technical and administrative functions that have ban developedaccordingto the requirements of production, and detailed in a Shipbuilding Policy. In this case, when new orders are received only work which is significantly different from any previously undertaken needs to reinvestigated in depth in order to identify possible difficulties.

Where it has not been Possible to minimize product variety, such investigations will become crucial to the effective operation of the shipyard. The outcome of these investigations is the Build Strategy Document.

A Build Strategy is a unique planning tool. By integrating a variety of elements together, it provides a holistic beginning to end perspective for the project development schedule. It is also an effective way of capturing the combined design and shipbuilding knowledge and processes, so they can be continuously improved, updated, and used as training tools.

A Build Strategy effectively Concentrates traditional meetings that bring all groups involved together to evaluate and decide on how the ship will be designed, procured, constructed, and tested before any tasks are commenced or any information is "passed on"

The objectives of the Build Straegy Document are as follows:

- To identify the new vessel.
- To identify the design and features of the new vessel.
- To identify contractual and management targets.
- To identify departures from the shipyard's shipbuilding Policy.
- To identify constraints, based on the new vessel being designed/constructed, particularly with reference to other work underway or envisaged.
- To identify what must be done to overcome the above constraints.

The last objective is particularly important as decisions taken in one department will have

implications for many others. This means that effective interdepartmental communication is vital.

The very act of developing a Build Strategy will have benefits due to the fact that it requires the various departments involved to communicate, and to think rationally about how and where the work for a Particular contract will be performed. It will also all holder highlight any potential problems and enable them to be addressed well before the "traditional" time when they will arise.

If a Shipbuilding Policy exists for the company, then it should be examined in order to ascertain if a Ship of the type uder consideration is included in the delivery g preferred product mix. If such a ship type exists then certain items wi;; already have been addressed.

These items included:

- outline build method,
- work breakdown structure,
- coding
- Workstation
- standard interim products,
- accuracy control,
- ship definition methods,
- planning framework,
- physical resources at shipyard, and
- human resources.

One thing which is unique to any new ship orderis how it fits in with the ongoing work in the shipyard. The current work schedule must be examined in order to fit the ship under considemtion into this schedule. Key dates, such as cutting steel keel laying, launch and delivery will thus be determined.

Using the key dates other events can be planned. These events are:

- key event program,
- resource utilization,
- material and equipment delivery schedule,
- material and equipment ordering schedule,
- chawing schedule,
- schedule of tests and trials, and
- stage payment schedule and projected cash flow.

Once the major events and schedules are determined, they can be examined in detail to expand the information into a complete build strategy. For example, the key event Program can be associated with the work breakdown to produce planning units and master schedules for hull, blocks, zones, equipment units, and systems.

The Build Strategy Document should be used by all of the departments listed above, and a formal method of feedback problems and/or proposed changes must be in place so that agreed procedures cannot be changed without the knowledge of the responsible person. Any such changes must then be passed on to all holders of controlled copies of the Build Strategy.

The Build Strategy is used to facilitate and strengthen the communication links. It should bring up fron, and be used to resolve, potential conflicts between departments in areas of design details, manufacturing processes, make/buy decisions and in the delivery goals.

A Build Strategy can be used as an effetive people empowerment tool by giving participants the opportunity to work out all their needs together in advance of performing the tasks.

The intent of a Build Strategy is to disseminate the information it contains to all who can benefit from knowing it. Throughout this report it is described as a hard copy document, but today it could well be electronically stored and dissemianted through local area network work stations.

Producing a Build Strategy Document will not guarantee an improvement in productivity, although, as stated earlier, the process of producing the document will have many benefits. Full benefits will only be gained if the strategy is implemented and adhered to.

Positive effects of the Build Strategy approach are two-fold:

- During production managers and foremen have a guidance document which ensures that they are fully aware of the construction plan and targets, men those relating to other departments. This reduces the likelihood of individuals making decisions which have adverse effects in other departments. Although often quoted by shipyards as being the reason for a Build Strategy, the benefits accruing from this are not major.
- Prior to production the use of the Build Strategy approach ensures that the best possible overall design and production philosophy is adopted. Crucial communication between relevant departments is instigated early enough to have a significant influence on final costs. It is therefore the structural cross-discipline philosophy which provides the downstream reductions in costs, and this is the major benefit.

A yard which develops a strategy by this method will gain all the advantages, whether or not a single

Build Strategy Document is produced. However. the imposition of the requirement for a Single document should ensure that the development of the strategy follows a structured approach

Perhaps the single most beneficial aspect of a Build Strategy is, that by preparing one, the different departments have to talk to each other as a team at the right time. A Build Strategy is a "seamless" document. It crosses all traditional department boundaries. It is an important step in the direction of the seamless enterprise. The most evident benefit is improved communication brought about by engaging the whole company in discussiom about project goals and the best way to achieve them. It eliminates process/rework problems due to downstream sequential hand-over of tasks from one department to another by defining concurrently how the ship will be designed and constructed.

Some of the advantages mentioned by users of the Build Strategy approach are:

- helps prioritize work
- seines as an effective team building tool,
- requires that people share their viewpoints because they need to reach consensus,
- places engineers face to face with the customers - purchasing production, test, etc.,
- expands peoples view of the product (ship) to include such aspects as maintenance, customer training support service, etc.,
- fosters strong lateral communication,
- saves time through concentration on parallel versus sequential effort
- facilitates resolution of differences and misunderstandings much earlier,
- greatly improves commitment ("buy in") by participants and the effectiveness of the hand-Over later,
- serves as a road map that everyone can be see and reference as to what is happening,
- facilitates coordinated communicatiom and
- develops a strong commitment to the process and successful completion of the project.

There are a few disadvantages mentioned by users, such as:

- effort and time to prepare the format Build Strategy document,
- total build cycle appears longer to some participants due to their earlier than normal involvement,
- cross functional management is not the norm and most people currently lack the skills to make it work,
- experts who used to make independent decisions may have difficulty sharing these decisions with others in developing the Build Strategy, and
- a Build Strategy describes the complete technology utilized by a shipyard and if given to a competitor, it could negate any competitive advantage.

However, the users felt that the advantages greatly outweigh the disadvantages.

PERFORMANCE OF THE PROJECT

Although it was known that a number of U.S. shipbuilders have utilized Build Strategis it was not known how many and how effective they were.

A number of shipyards and the U.S. Navy believed in the benefit of the Build Strategy approach and this project was undertaken to accomplish the following objectives

- To determine, for a number of U.S. shipyards involved in building the selected ship types, capabilities and limitations, and to classify them into common U.S. industry criteria.
- To determine how many U.S. shipbuilders currently use formal documented Build strategies.
- To familiarize U.S. Shipbuilding personnel with the Build Strategy approach requirements, and benefits.
- To determine U.S. shipyard perceived need for a formal Build Strategy.
- To prepare a generic Build Strategy that can be used by U.S. Navy program office during concept, preliminary, and contract design as well as U.S. shipyards, as the basis for the Build Strategy for a specific project.
- To prepare specific examples of the use of the generic Build Strategy for two seleted ship types.
- To provide a final report on the findings of the shipyard survey on the use of formal Build Strategies, the perceived requiremem shipyard capabilities and limitations and how they were used/incorporated into the generic Build Strategy.

SELECTION OF SHIP TYPES

Four ship types were offered as potential examples to the PaneI Project Team, namely;

- Destroyer,
- Fleet Oiler,
- RO RO, and
- container.

The Team selected the fleet oiler and the container ship in January 1993. As the project developed and the industry interest shifted even more from military to commercial ships, a number of sources recommenced that the fleet oiler example be changed to a products tanker. Therefore the final examples that were selected to demonstrate the use of the Build Strategy Development framework were a 42,400 tonne DWT Product Tanker and a 30,700 tonne DWT Container/RO RO ship.

Attempts to get ship design informartion from U.S. sources, for ships of these types recently designeds and/or constructed, were unsuccessful. Therefore, art A&P Appledone design for a products tanker and the MarAd PD-337 Commercial Cargo Ship (non-enhanced) design were used for the examples.

QUESTIONNAIRES

BUILD STRATEGY and SHIPYARD CAPABILITIES AND LIMITAITONS questionnaires were prepared for distribution to U.S. and Canadian shipbuilders. Their purpose was to determine current understanding and use of the Build Strategy approach and to determine current capabilities and limitations regading building of selected ship types so that 'common capabilities and limitations" could be developed and used in the two Build Strategy examples.

Both questionnaires were sent to 22 private and Navy Shipyards. Questionnaires were received back from three shipyards. The Build Strategy Questionnaire was completely filled out in all three cases. The Shipyard Capabiity and Limitation Questionnaire was only completely filled out by one shipyard. with the other ship completing from 30 to 50 percent Only one of the shipyards that responded to the questionnaires was willing to meet with the project team. Two other shipyards agreed to a team visit during telephone calls to solicit support for the project. The Build Strategy Questionnaires were also completed for two shipyards that were visited but had not completed the questionnaires.

All five shipyards responding to the Build Strategy Questionnaire were familiar with the Build Strategy approach. Only one had never prepared a Build Strategy document, although even that shipyard did prepare many of the listed content components and was of the opinion that it was not worth the effort to produce a single Build Strategy

There were wide differences in the need for many of the listed content components to be in the Build Strategy document However, 18 out of 51 components were identified by at least four Shipyards and another ll components by at leas t three shipyards. These 29 components were identified as Build Strategy "recommended" components. Two components in the Construction Data group, namely: Number of Plate Parts and Number of Shape Parts, were considered unnecessary by all fiveshipyards. They Will not be includcd in the Build Strategy Document. The remaining 20 components were identified as "optional'.

The lack of response made it impossible to determine common capabilities and limitations. However, the following findings are presented

- Two shipyards have existing Marketing Departments. Which are involved in Market Research Interestingly, they both have only been involved in Navy or government contracts during the past decade.
- One shipyard has a central planning and scheduling the others have Master Planning Group that integrates the planning and scheduling of the various departments.
- Two Shipyards have separate Material Planning/Control Groups and all three shipyards that responded to the questionnaire use mater material coding MRP II or similar
- Only one shipyard has a complete in house engineering capability. Both the other shipyards subcontract most of their engineering to marine design agents.
- Two shipyards use CAD concurrent engineering production oriented drawing, standard engineering procedures and engineering standard details.
- All three shipyards have complete in-house lofting capability that are part of the engineering department.
- Two shipyards have Manufacturing Industrial Engineering groups that are part of the Production Department.

- Engineering in all three shipyards is functionally organized into the traditional hull. machinery and electrical although their work is prepared for block construction and zone outfitting.
- Two shipyards use self-elevating, self-propelled transporters up to .250 ton capacity, and both self and non-elevating trailers from 50 to 80 ton capacity. Fork lift trucks from 1 to 14 ton capacity are used for general material handling.
- All three sbipyards claim to use block construction, zone outfitting and packaged machinery units. They all claim to use Accuracy Control for structure and one shipyard it for piping ventilation and electrical components.
- All three shipyards have state of the art painting capabilities.

U.S. SHIPYARD VISITATION

The project team visited BethShip, Avondale Shipyards and NASSCO. Each visit lasted a minimum of four hours with one taking six hours. A proposed agenda was sent to each shipyard prior to the meetings, along with a number of additional questions which would be asked during the visit. The project team first presented background information on the project, such as description, objectives and approach. Then the purpose of the meeting was presented, which was to discuss face to face the questionnaire responses and clarify any questions. It was also to see what each shipyard had done, and was (doing, with regard to Build Strategy. In addition the Shipbuilding Technology Office of the Naval Surface Warfare Center at Carderock, was visited. The purpose of this visit was to learn about the Generic Build Strategy activity being worked on for the Mid Term Fast Sealift Ship (MTFSS) program. The purpose of the meeting was to determine how the two projects and should interact. The Navy reported that there was considerable confusion in the industry because of identical project titles, and concern regarding the relationship of the SP-4 Panel Build Strategy project and the U.S. Navy's Mid Term Fast Sealift Ship program Questions being asked ranged from "Are they connected?" to "How are the two projects going to be differentiated?" There is no contractual connection. The MTFSS program is interested in using the Build Strategy approach for one specific ship in a number of shipyards to reduce the time taken from contract award to delivery of the ship. The SPA project is interested in showing many shipyards how to use the Build Strategy approach for any ship type. The visit was most beneficial in determining this difference and resulted in agreement that it was necessary to differentiate between the two projects to the maximum extent possible. It was mutually decided to rename the SP-4 project and further, to concentrating entirely on commercial shipbuilding and ship types. It was decided to Clearly differentiate between the two projects by changing the title of the SP-4 project to BUILD STRATEGY DEVELOPMENT.

All shipyards and the Shipbuilding Technology Office were very cooperative and generous in the giving of their time and sharing of their experiences and information

All three shipyards were familiar with the Build Strategy approach and had prepared a number of Build Strategies in preparation of bids. Ship types involved were container ship and product tanker. Two had used Build Strategies for at least one complete design/build cycle. Ship types involved were container, sealift conversion and T-AGS.

The departments having the major responsibility for the Build Strategy Development were under Production in two shipyards and part of Advanced Product Planning and Marketing in the other shipyard.

All three shipyards were committed to using the Build Strategy approach in continuing greater scope. 'This was entirely based on their own perceived needs/benefits and being driven by external demands or pressure.

The project team was able to review recent Build Strategies at each shipyard and was impressed by the level at which they were being used. Build Strategy size ranged from 100 to 300 pages... Typical effort ranged from 400 to 2000 man hours. Howwer, it was pointed out that most of the effort would be required in any case. It simply was being performed earlier, up front, in a formal and concurrent manner. Based on this, the additional effort to prepare a Build Strategy is likely to be about 400 hours. Obviously, the first time it is done, the additional effort may be considerably more as the new approach must be learned in a team environment and many traditional barriers broken down.

By this review and discussion of the Build Strategies, it was possible to determine the items which were considered by the shipyards to be essential which items were optional, and what should not be included in the Build Strategy document.

The project team emphasized that it was necessary for each shipyard to have a documented Shipbuilding Policy on which to base their Build Strategies.

Otherwise, each Build Strategy must contain the required policy components.

The shipyards had a number of concerns and emphasized the following requirements:

- Build Strategy document should not be so structured that it discourage innovation or the introduction of improved methods or facilities.
- It should not attempt to tell shipyards how to prepare drawings, build ships, define or limit block size or dictate required production information
- It should incaporate need for design for producibility and be a guide for continuous improvement and TQM
- The Build Strategy document and examples of its use should be based entirely on commercial Ships of the type likely to be built in the U.S. in the foreseeable future.
- It should not address military ships of any type.
- The Build Strategy document must treat all components of the desigt, build, and test process with equal attention. So often the "simpler" or "better known" front end design and production -Ions are more than adequately treated, but the back end processes, such as system tests and compartment check off, are given minimum consideration in a Build Strategy.
- The two examples of the Build Strategy document use should emphasize the ship type major differences and their impact on the Build Strategies.
- The project should emphasize the benefits of the formal Build Strategy approach In doing this an attempt should be made to determine which world class shipbuilders the Build Strategy or similar approaches.
- The project should also clearly describe the pre-requisites that a shipyard should have or develop before undertaking a Build Strategy to ensure the best chance of an effective Build Strategy being developed and implemented.
- The use of preliminary and detailed Build Strategies should be clearly described.
- The project should provide documentation that is suitable for use as an educational ted.

Because of the reluctance of most shipyards that were contacted to share the detailed information requested by the Shipyard Capabilities and Limitations Questionnaire, no renewed attempt was made to obtain this information during the visit. Instead, each Shipyard visited was asked what were the two or three major limitations. All three shipyards mentioned crone capacity. They would all like to erect larger blocks than currently possible. One shipyard would like to increase crane capacity throughout the fabrication and assembly shops, as well as for block erection on the ways or in the dock. Another shipyard would like to have more covered (out of the weather) buildings for assembly and block construction. Finally one shipyard mentioned that its major limitation was timely engineering.

U.S. SHIPYARD COMMON ATTRIBUTES

As previously mentioned, due to lack of response to the shipyard Capabilities and Limitations Questionnaire, it was not possible to determine U.S. shipyard common attributes which could be used in the Build Strategy Document. In order to have a basis on which to prepare the project Build Strategy Document and examples of its use, a hypothetical shipyard was defined by the pjectteam. The hypothetical shipyard represents no existing U.S. shipyard but rather attempts to reflect some of the facilities and capabilities of a typical U.S. shipyard that would be interested in competing in the world commmercial ship market. It does not reflect the lowest common capabilities.

FOREIGN SHIPYARD VISITATION

Eight foreign shipyards were contacted, but only four responded and three of them agreed to a visit.

Visits to the three foreign shipyards were made in June and July, 1993. The shipyards were Ferguson's in Port Glasgow, Scotland, a successful small Shipbuilder Odense Steel Shipyard in Denmark a suceessful large shipbuilder reputed to be one of the best shipbuilders in the world today and Astilleros Espanoles in Spain, another succeessful large shipbuilding group which has utilized many of the NSRP project publications to assist them in their improvement program

All shipyards visited gave outstanding support in time and effort to the team and their hospitality was exceptional They were most open in showing and describing their facilities, processes, goals and problems, and all stated that their willingness to participate in projects to help the U.S. shipbuilding industry improve was based on the belief that everyone benefits from an open exchange of technology, a sharing of problems, and the development of solutions for their resolution.

Ferguson's does prepare a Build Strategy for each contxact. They cover most of the recommended items in the study proposed Build Strategy Document List. Most of the optional items are omitted. although they do include budgets. Build Strategy with budgets are given restricted distribution. The Prodution Engineering Group has the responsibility to prepare the Build Strategies with input from other groups/departments.

Ferguson's Build Strategy is relatively simple (that's how they like it), but even with their small size they still see and achieve benefits from using the Build Strategy approach Ferguson's uses previous Build Strategies as the basis fornew Build Strategy.

Ferguson's approach was to accept mid-1980 facilities and to concentrate on using their people more effectively through integrated processes.

Odense Steel Shipyard (0SS) has excellent facilities with up to date equipment and processes. They have an extensive ongoing facilities improvement program. They arenot satisfied withany phase ofthe operation and are always seeking continuous impromovement. They are currently building today what they did in the past with 40% of man hours. 0SS believes productivity is the key to future success in global shipbuilding. They have a goal of 6% annual productivity improvement.

Typical build cycle is 12month with 3 month in the building dock, one month outfitting and 3 weeks deck trials and sea trials. Sea trials are normally 3 days and once the shipleaves the shipyard for sea trials it does notretumtoshi-

OSS does not use the Build Strategy approach but has a planning system that covers most of the Build Strategy components and recognizes the need to communicate this information in a formal manner to the many users in a shipyard. OSS was not a ware of the Build Strategy approach. However, the way they prepare and formally document and distribute their planning documents achieves some of the same objectives. OSS does have a long term business plan and the Phase I part of the planning process is similar to the shipbuilding Policy. Their planning is totally integrated 0SS has always used standard processes and standard details to the maximum extent. They are an effective part of 0SS high productivity in all departments and processes . 0SS has very up to date capabilities and is in the fortunate position of having no known limitations for the foreseeable future.

Astilleros Espanoles is a grouping of diverse shipyards covering all sizes of commercial ships and of shore vehicles /rigs. They have a central office in Madrid. This central group performs much of the business planning and setting of each shipyard policy. However. at the meeting with representatives of all shipyards in the group, and at meetings at Sestau and Peurto Real Shipyards. the enthusiasm of individual managers for continuous improvement including the use of a Build Strategy approach was very clear.

Each shipyard has its own 5 year plan covering goals, productivity. ship types and employees. A major point in their use of Build Strategy is the development of a catalog of interim products for each shipyard. Build Strategies were reviewed in two shipyards. They covered most of the recommended items in the study proposal Build Strategy Contents List In addition, they added interesting information about the ship Owner, his existing fleet and operations. The Study proposed Build Strategy Contents List was modified to incorporate this additional item as an option

Astilleros Espanoles shipyards cover the range from old shipyards to relatively new facilities but in all cases they have had significant modernization in the last few years, some of which is still underway. Only one shipyard acknowledged any limitations, and that was the clear width of a bridge through which its ships hadtopass to get to thesea.

All of the shipyards visited stated that improvement in productivity was the key to survivability and time success in the global shipbuilding marketplace.

BUILD STRATEGY DOCUMENT CONTENTS LIST

A contents list shown in Table III was developed for the Build Strategy Document from the questionnaire responses, as well as from shipyard visit discussion. The actual Build Strategy Document and the two examples followed this contents list. An introduction outlining the purpose of the Build Strategy Document, its suggested distribution in a shipyard and the prerequisites for a successful Build Strategy was also provided.

TABLE III
PROPOSED BUILD STRATEGY
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R IS RECOMMENDED
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2.3 Special Characteristics &Requirements	R
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6.3.3 Equipment Units	R
6.3.4 Systems	R
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6.4.1 Hull Blocks	R
6.4.2 Zones	R
6.4.3 Equipment L-nits	R
6.4.4 Systems	R

6.5 Hull Production Strategy
6.5.1 Preliminary Process Analysis o
Integration of Outfit
Process Analysis By Block
6.5.2 Non Standard Interim Products o
6.5.3 Build Location & Launch Condition R
6.5.4 Erection Schedule R
6.6 Machinery Space Outfit Strategy
6.6.1 Equipment Units R
6.6.2 On Block Outfitting R
6.6.3 On Board Outfitting R
6.7 Accommodation Outfit Strategy R
6.8 Cargo & Other Space outfit Strategy
6.8.1 On Block Outfitting R
6.8.2 On Board Outfitting R
6.9 Painting Strategy
6.9.1 Outline Paint Specification o
6.9.2 Pre-Painting R
6.9.3 Primer Repair Strategy R
6.9.4 Unit/Block Painting Strategy R
6.9.5 Zone Painting Strategy R
6.9.5.1 Machinery Spaces
6.9.5.2 Outside Shell and Decks
6.9.6 Special Considerations R
6.10 Sub-Contract Requirements
6.10.1 Bought-In Items R
6.10.2 Use of On-Site Sub-Contractors R
6.11 Productivity
6.11.1 Productivity Targets R
6.11.2 Comparisons/Differences From
Previous Vessels R
6.12 Temporary Services
5.12.1 staging Plan R
5.12.2 Access& Escape Plan o
6.12.3 Power & Lighting o
6.12.4 Weather Protection o

7: ACCURACY CONTROL
MANAGEMENT PLAN
7.1 System Critical Dimensions & Tolerances
7.2 Interim Product Critical Dimensions &
Tolerances R
7.3 sampling Plan o
7.4 Special Procedures o
7.5 Jigs & Fixtures o
7.6 HOt Work Shrinkage
7.6.1 Use of Extra Stock 0
7.6.2 Shrinkage Allowances 0
7.6.3 Distortion Control 0

8: TEST& TRIALS
8.1 Test Planning
8.1.1 Strategy R
8.1.2 Schedule (High Level) R
8.2 Pre-Completion Testing
8.2.1 Pre-Survey & Survey 0
8.2.2 Pipe Pre-Testing 0
8.2.3 Equipment Unit Pre-Testing 0
8.3 Tank Test Schedule R
8.4 Equipment Unit Test Schedule R
8.5 Pipe Unit Test Schedule R
8.6 Zone Close-Out Strategy R
8.7 Principal Trials Items R

9: PERSONNEL
9.1 Industrial Relations Aspects
9.1.l Design o
9.1.2 Sub-Contract 0
9.2 Training 0
9.3 Project Organization
9.3. 1 Shipyard Organization Charts R
9.3.2 Client's Organization Charts R

10: WEIGHT CONTROL
10.1 General
10.2 Outline Procedure R
10.3 Departmental Responsibilities

ACKNOWLEDGMENTS

Thispaper is based on a report prepared jointly by A&P Appledore International Ltd. and Thomas Lamb, and covers the preparation distribution and analysis of the responses to the Build Strategy and Shipyard Capabilities and Limitations Questionnaires a summary of the visits to both U.S. and foreign shipyards; the attempt to develop U.S. shipyard Common Attributes prerequisites for the use of Build Strategies, the Build Strategy Document and the examples of its use.

Both questionnaires were jointly developed by A& P Appledore International Ltd and Thomas Lamb. However, without the participation of the shipyards who took the time to respond to the questionnaires and those that agreeed to allow the project team to visit and dicuss the subject further, this report would haveno value. Their contributions are acknowledged with appreciation.

The project was funded by the National Shipbuilding Research Program Design/Production Integration Panel (SP-4), at the time chaired by J. Getz of Bethlehem Steel Shipyard.

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Presentations to Norfolk Shipbuilding by A&P Appledore in 1983, and to Lockheed Shipbuilding and Tacoma Boatbuilding in 1984

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NATIONAL SHIPBIULDING RESEARCH PROGRAM

PRODUCT ORIENTED WORK BREAKDOWN STRUCTURE

DESIGN FOR PRODUCTION INTEGRATION

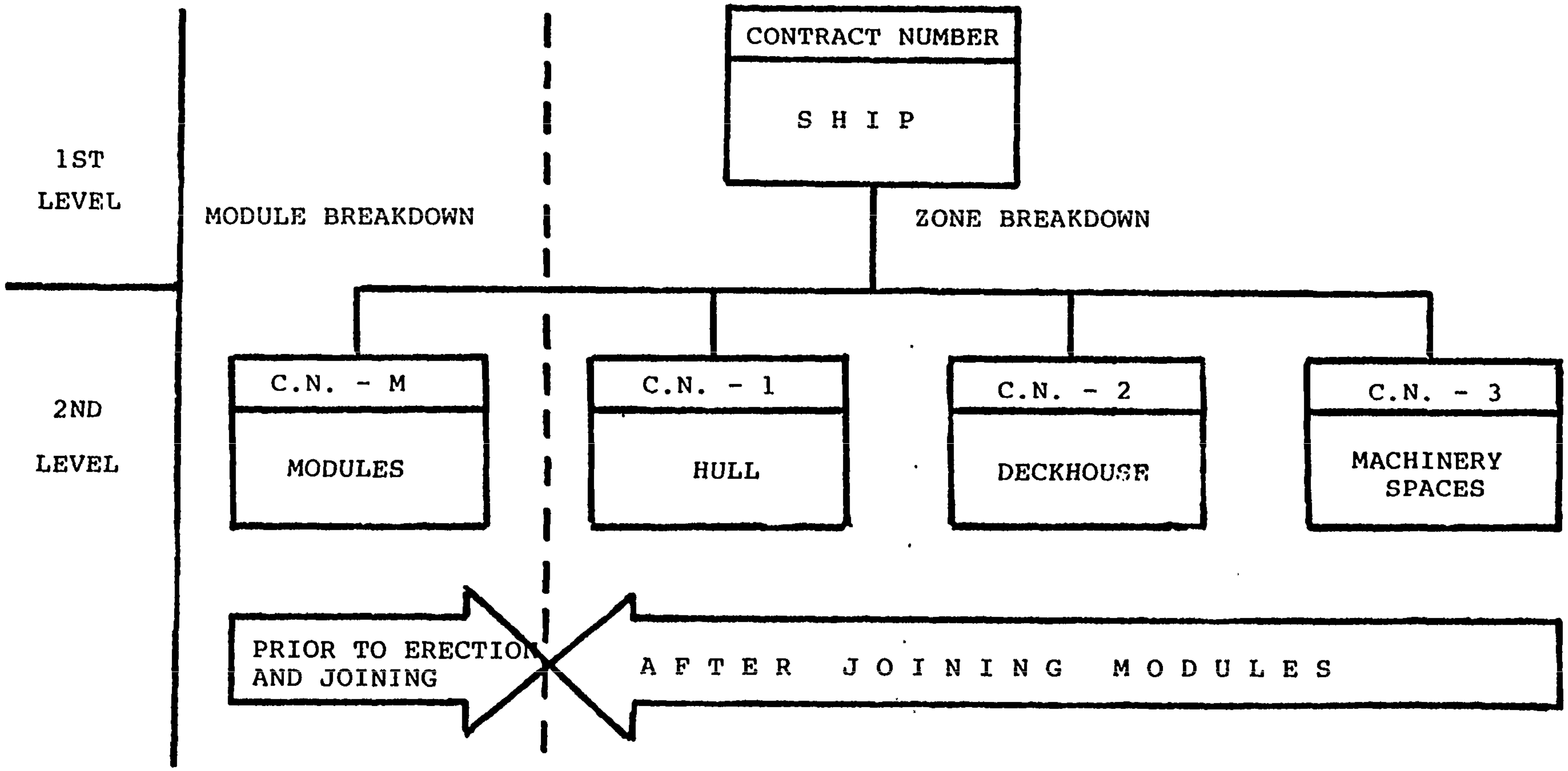


FIGURE 2.7.9 - SHIP BREAKDOWN STRUCTURE

PRODUCT-ORIENTED WORK BREAKDOWN STRUCTURE

CASE FOR ACTION

1. Work Breakdown Structures (WBS) form the basis for cost collecting and estimating.

2. Current WBS do not facilitate costing of ship design and production alternatives.

3. Because they do not reflect how ships are built current WBS do not facilitate accurate cost estimating.

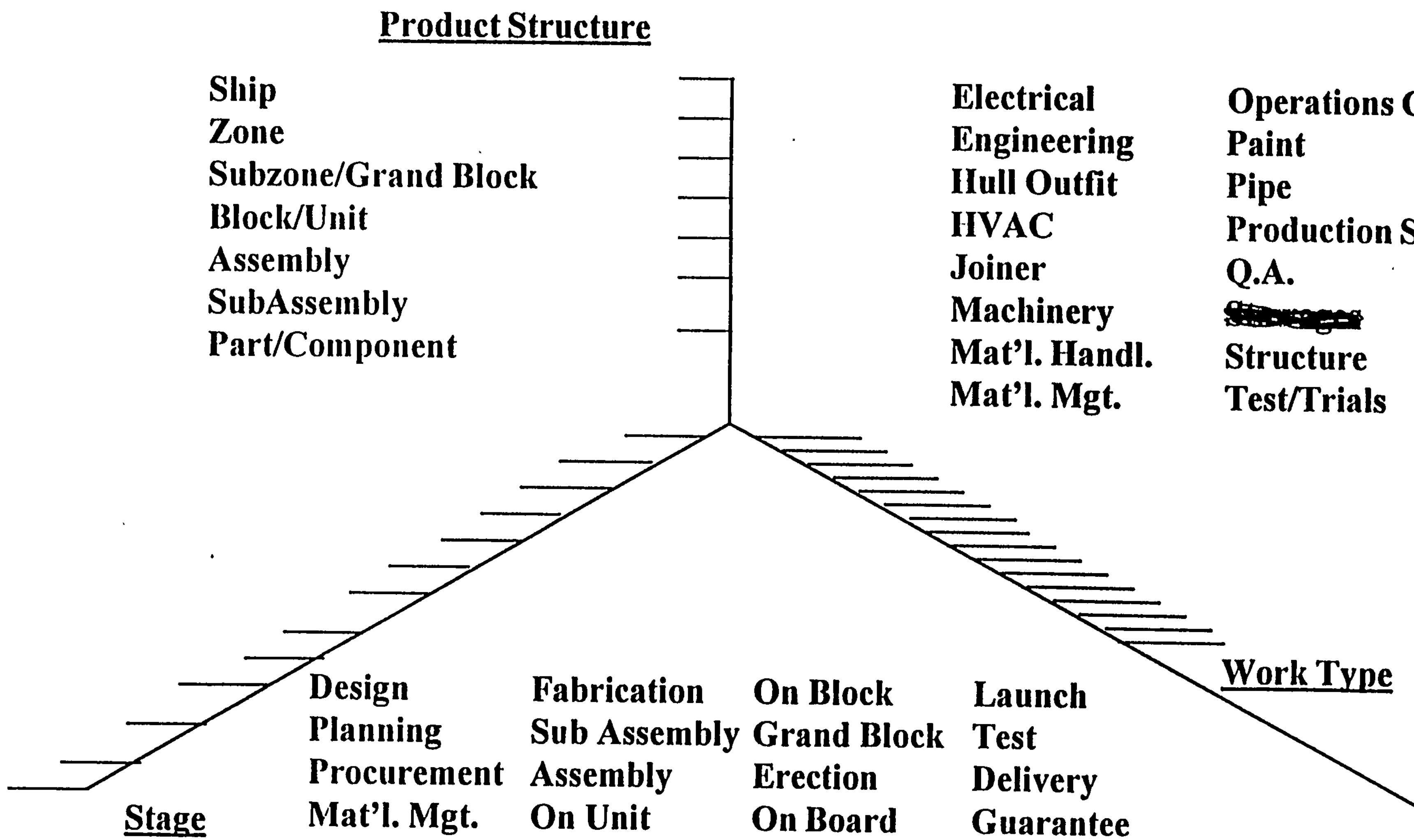
4. Through use and familiarity with current WBS designers (both Navy and private shipbuilders) have “system” mindsets that conflict and constrain their ability to design ships using world class shipbuilding methods.

PRODUCT-ORIENTED WORK BREAKDOWN STRUCTURE

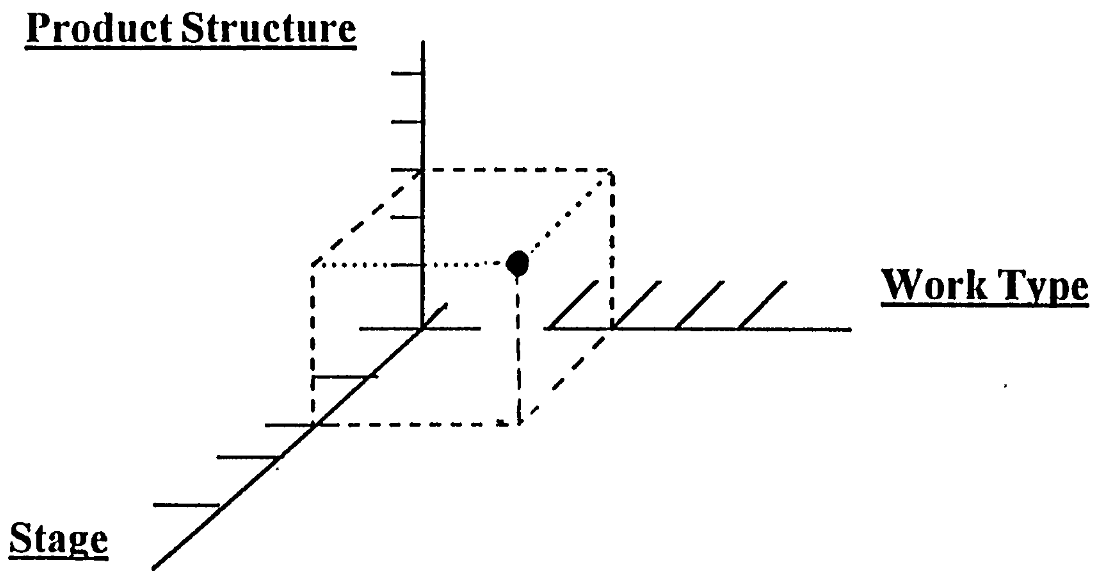
VISION

A Product-oriented Work Breakdown Structure (PWBS) reflects current and accommodates future changes in world class shipbuilding practices and how ships are built, that can be used by U.S. shipyards to assist them to design easily producible ships, improve accuracy of cost estimating and logic of planning, and to educate design, cost planning and other shipyard and their supplier personnel.

PWBS Model

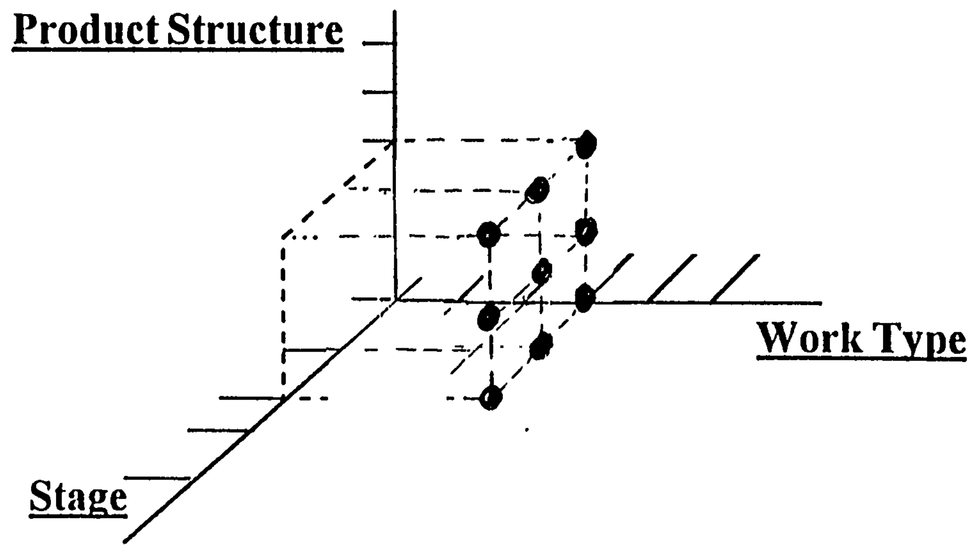

Product Structure
Ship
Zone
Subzone/Grand Block
Block/Unit
Assembly
SubAssembly
Part/Component
Electrical
Engineering
Hull Outfit
HVAC
Joiner
Machinery
Mat'l. Handl.
Mat'l. Mgt.
Operations Contr.
Paint
Pipe
Production Serv.
Q.A.
[redacted]
Structure
Test/Trials
Work Type
Stage
Design
Planning
Procurement
Mat'l. Mgt.
Fabrication
Sub Assembly
Assembly
On Unit
On Block
Grand Block
Erection
On Board
Launch
Test
Delivery
Guarantee

PWBS Examples



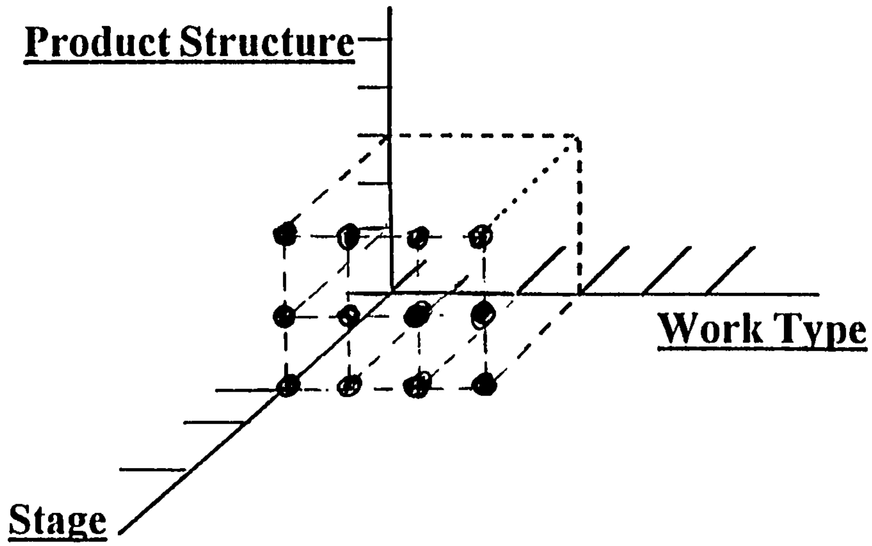
. Represents the cost of the Interim Product for a single stage and a single Work Type.

PWBS Examples



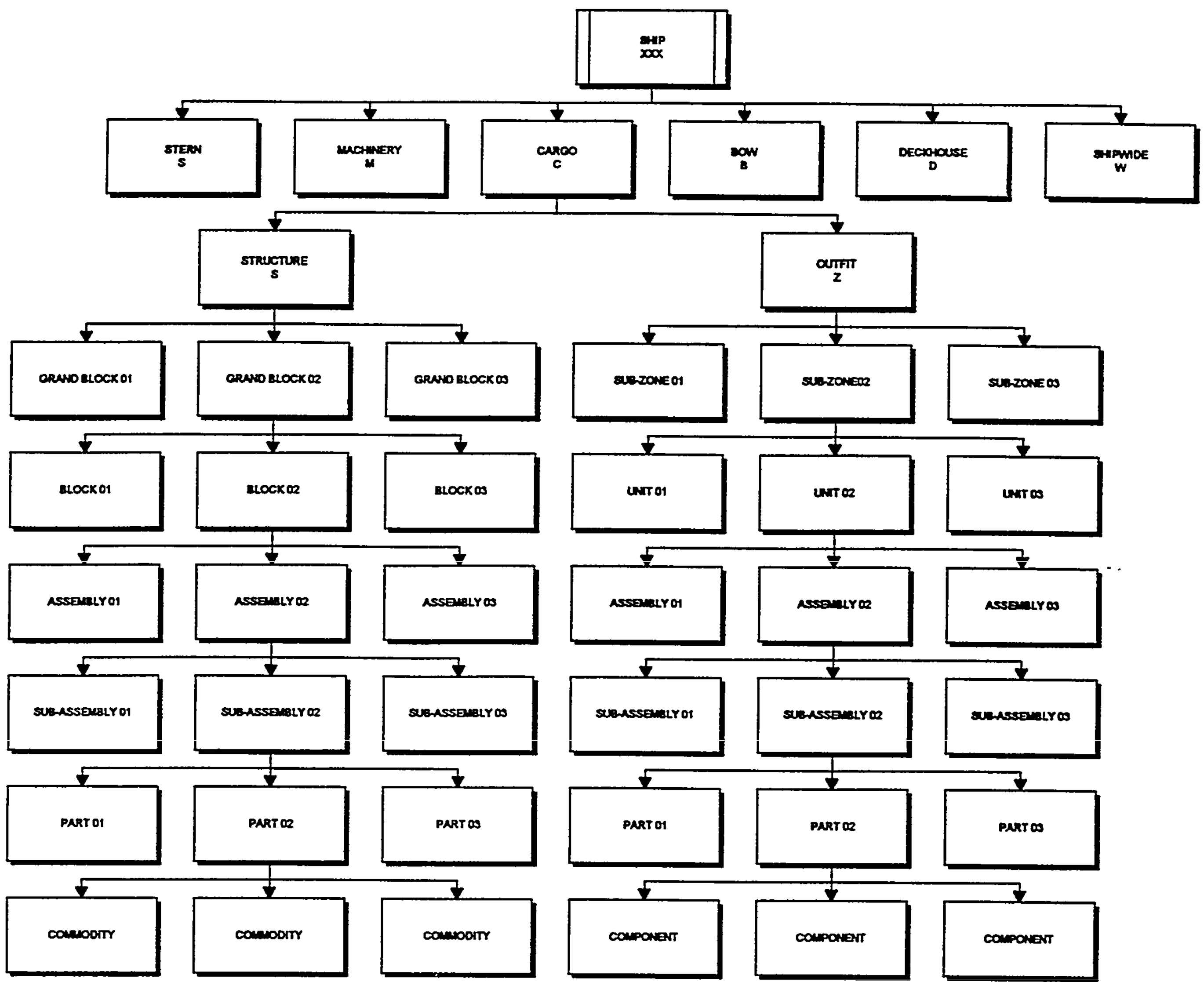
. Represents the cost of the Interim Product for Multiple Stages and a single Work Type.

PWBS Examples

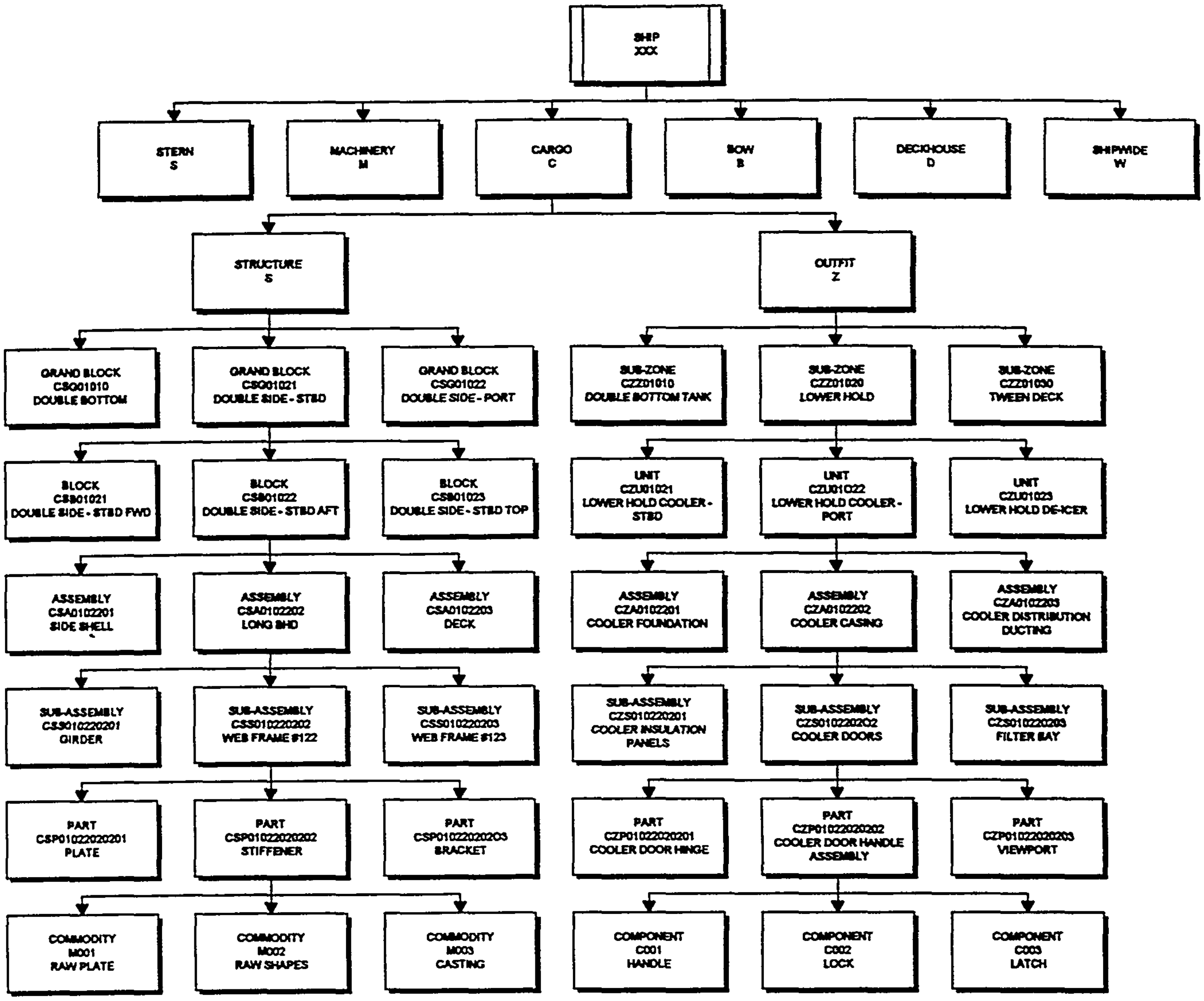


. Represents the cost of the Interim Product for Single Stage and Multiple Work Types.

PRODUCT BREAKDOWN STRUCTURE



PRODUCT BREAKDOWN STRUCTURE



MID-TERM SEALIFT SHIP PROGRAM

PRODUCT WORK BREADOWN STRUCTURE

CODING

INTRODUCTION

The Generic Build Strategy Task, in Phase 2 of the Mid-Term Sealift Ship Program, included the requirement to develop a Product Work Breakdown Structure (PWBS) that would support both the use of the Generic Build Strategy by the Navy and its shipbuilders and the ongoing Product Oriented Design and Construction (PODAC) Cost Estimating Model.

It was originally intended to develop this PWBS in Phase 1 of the program, based on sample PWBSs provided by the participating shipyards, however, this was not accomplished even though the shipyards did provide the samples, or at least a description of their approach to PWBS.

A team was formed to develop the required PWBS. The team consisted of members from D&P Inc. (the Mid-term Sealift Ship Program Manager), the participating shipyards, Naval Surface Warfare Center, the ERAM Team and University of Michigan Transportation Research Institute.

A Vlsion, Objectives and Strategies were prepared and then a Plan of Action and Milestones (POA&M) established. One of the tasks identified in the POA&M was to develop coding for the PWBS.

A Coding sub-team was setup within the PWBS team to develop recommendations for a code that would be applicable to the PWBS. This report records the findings and recommendations of the Coding sub-team.

SCOPE OF WORK

The Coding sub-team established its own POA&M as follows:

1. Peform a literature search for Classification and Coding

2. Review appropriate literature and select a coding approach that best fits the PWBS. Include a discussion of the review findings, approach advantages and disadvantages, and selection decisions.

3. Recommend the selected coding approach and present basis for recommendation. Also include examples of how the coding would be used.

4. Develop coding for PWBS and necessary documentation

LITERATURE SEARCH

A literature search was performed by UMTRI and it discovered 39 relevant items. These are recorded in Appendix A Of these 20 were found to be worth review and this was accomplished. After review 6 items were considered to be meaningful to the development of the PWBS Codingand expanded abstracts were prepared for them. The expanded abstracts are included in Appendix B and are referred to in the discussion of coding approaches.

Review of the 6 selected articles did not provide any existing approach that was directly usable for the PWBS Code, nor did it provide any new or innovative way to approach the coding. However the review did provided confirmation for the recommendations that were made by the PWBS Coding Team.

CODING APPROACHES

Coding types can be of three types, namely

Monocode, which is a pure hierarchical code
Polycode, which is a matrix code and
Hybrid-code, which is a mixture of Mono and Poly codes.

Most codes are hybrid codes but both pure mono and poly codes are used in various industies.

An example of a monocode and a polycode is given below:

INTERIM PRODUCT	MONOCODE	POLYCODE
GRAND BLOCK	11	GO11
BLOCK	111 112 11X	B023
ASSEMBLY	1111 1112 1113 111X	A041
SUB-ASSEMBLY	11111 11112 11113 11114 1111X	S023
PART	111111 111112 111113 11111X	P079

It can be seen that the monocode requires more digits to represent a final part but it is claear from the code where the part belongs to right up to the grand block.

Codes can be numeric, alphabetic or Alpha-numeric. In the past, computer capability constrained both the available field length (number of digits) and the use of alpha-numeric codes. Today computer capabtity has no practical constraints. However, past perceptions, internal system constraints and preferences sometimes still limit the development of the best approach for today’s technology and this must be guarded against.

One of the disadvantages of numeric codes is that if they are more than 5 digits, it has been found necessary to separate the fields with spaces or dashes to help coders. Strings of more than 5 numbers have been found to be error prone by data coders. Alpha-numeric codes do not have this problem as the alphabetic characters form effective separators and appear to be natural breaks for the coders. The monocode example above is a pure numeric code whereas the polycode example is an alpha-numeric code. An alphanumeric code for the monocode example could look like the following

GRAND BLOCK		**G1**		
BLOCK	**G1B01**	**G1BO2**	**G103**	**G1XX**
ASSEMBLY	**G1B01A01**	**G1B01A02**	**G1B01A03**	**G1B01AXX**
SUB-ASSEMBLY	**G1B01A01S01**	**G1B01A01S02**		**G1B01A01SXX**
PART	**G1B01A01S01P01**	**G1B01A01S01PO2**		**G1B01A01S01PXX**

It can be seen that the alpha-numeric code for the monocode takes more digits than the pure numeric code to describe the interin products. However, as stated above, if separators are required between the pure numeric code section for each level then the number of digits maybe the same as the alpha-numeric code.

Discussions with a number of shipyards showed that they were limited by internal systems to 6 to 12 digits for their current work breakdown structures. It also showed that no U.S. shipyard work breakdown structure had the full capability that was being developed for the PWBS. Never the less, it was decided to proceed with full capability that was required by the PWBS Team. Obviously, the Navy and the shipyards could choose to use only that part of the coding that was of interest to them or fitted their needs.

CODING REQUIREMENTS

The coding requirements, established by the PWBS Team, were that the coding should:

. Be capable of handling the 3 dimensions of the PWBS model, that is, Product Structure, Stage and Work Type.

. Include coding/fields for Interim Products.

. Give consideration as to the need and benefit of including:

PWBS vision and objectives
Utilize and/or accommodate Group Technology
Sub-stages
Ship type
Drawings
Process

Schedule
Unit of measure
Quantity
Labor hours
Material Catalog
System
Find Number (number on drawing for each interim product)
Location

CODING SUB-TEAM RECOMMENDATIONS

The Coding sub-team presented the following recommendations to the full PWBS team at the meeting in New Orleans on November 15 and 16, 1995:

1. That separate fields be used for Ship Number (shipyard dependent), Product Structure, Stage, Work Type and Interim Product, as shown below.

SHIP NUMBER	PRODUCT STRUCTURE	STAGE	WORK TYPE

2. That a monocode (hierarchical) be used for the hierarchical Product Structure field and polycodes or hybrid codes be used as appropriate for the other fields.

3. That alpha-numeric and alphabetic codes be used.

Examples of such an approach are:

SHIP NUMBER	PRODUCT STRUCTURE															STAGE	WORK TYPE
	ZONE	STRUCTURE/ UTPUT INDICATOR	INTERIM PRODUCT INDICATOR	LOCATION			ASSEMBLY	SUB-ASSEMBLY	PART	COMMODITY COMPONENT	SHIP TYPE	INTERIM PRODUCT TYPE	ATTRIBUTE #1	ATTRIBUTE #2			
				LONGL	VERTICAL	TRANSV											
7408	B	S	P	01	01	0	02	13	13	M213	HBC	1	1	1		FB	ST
7408	B	Z	P	01	05	1	03	21	05	C244	VLC	1	3	3		FB	PI

5. Off the items listed by the PWBS team to be considered by the Coding sub-tearm, the following were considered not to be included in the code but to be items of other systems with which the PWBS would interface:

Schedule
Unit of measure
Quantity
Labor Hours
Location

However, the unit of measure and labor hours could be covered in an Interim Product Catalog the development of which is being recommended by the PWBS team.

PROPOSED CODING

The full code for the PWBS will consist of five fields consisting of:

SHIP NUMBER
PRODUCT STRUCTURE
STAGE
WORK TYPE

Ship Number

The ship number is shipyard specific and both field and format should be selected by the shipyard. No further discussion of this item is required.

Product Structure

The PWBS Product Structure will be coded as follows:

[1] By the ship number

[2] ZONE

Bow	B
Stem	S
Machinery	M
cargo	C
Deckhouse	D
Shipwide	W

[3] INTERIM PRODUCT CATEGORY

Grand Block	G
Sub-zone	Z
Block	B
unit	U
Assembly	A
Sub-assembly	S
Part	P
Commodity/Component	C

[4] LOCATION

Longitudinal	XX	XX denotes sequential number within each Sub-zone from forward to aft
Vertical	XX	XX denotes sequential number within each Sub-zone from bottom up
Transverse	XX	XX denotes sequential number within each Sub-zone, center O & even, Starboard uneven and Port even

[5] ASSEMBLY

ASSEMBLY XX XX denotes sequential number with each Block, Unit or Sub-Zone

[6] SUB-ASSEMBLY

SUB-ASSEMBLY XX XX denotes sequential number within each Assembly. Note may not belong to an assembly. Can go direct to Block Unit or Sub-Zone.

[7] PART

PART XX XX denotes sequential number within a sub-assembly or any other interim product.

[8] COMMODITY/COMPONENT

COMMODITY	MXXX	See Commodity Code Section below
COMPONENT	CXXX	See Component Code Section below

Most shipyards have existing commodity (raw material) codes and may even have a standard part numbering system for components (purchased equipment). It should be possible for them to simply USE their existing codes. For completeness of this coding system the following coing systems for Commodities and Components will be used:

COMMODITY CODE	COMMODITY DESCRIPTION		
MHPXX	Hull	Plate	Sequential Number
MHSXX	Hull	Shapes	Sequential Number
MHWXX	Hull	Welding Supplies	Sequential Number
MHIXX	Hull	Insulation	Sequential Number
MPPXX	Piping	Pipe	Sequential Number
MPFXX ‘	Piping	Fittings	Sequential Number
MPIXX	Piping	Insulation	Sequential Number
MSSXX	Sheet Metal	Sheet	Sequential Number
MSFXX	Sheet Metal	Fittings	Sequential Number
MECXX	Electrical	Cable	Sequential Number
MEFXX	Electrical	Fittings	Sequential Number

and so on.

COMPONENT

COMPONENT CODE		COMPONENT DESCRIPTION	
CHMXX	Hull	Mooring Fittings	Sequential Number
CHCXX	Hull	Container Fittings	Sequential Number
CHHXX	Hull	Hatches	Sequential Number
CHWXX	Hull	Water-tight Doors	Sequential Number
CHSXX	Hull	Special Equipment	Sequential Number
CMEXX	Machinery	Propulsion Engine	Sequential Number
CMSXX	Machinery	shafting	Sequential Number
CMPXX	Machinery	Propulsory	Sequential Number
CMCXX	Machinery	Controls	Sequential Number
CEPXX	Electrical	Power Generation	Sequential Number
CEDXX	Electrical	Power Distribution	Sequential Number
CELXX	Electrical	Lighting Equipment	Sequential Number
CECXX	Electrical	Command & Control	Sequential Number
CENXX	Electrical	Navigation Equipment	Sequential Number
CEMXX	Electrical	Communication Equip	Sequential Number
CERXX	Electrical	RADAR Equipment	Sequential Number
CAHXX	Auxiliary	HVAC Equipment	Sequential Number
CASXX	Auxiliary	Sea Water Equipment	Sequential Number
CAFXX	Auxiliary	Fresh Water Equip.	Sequential Number
CAUXX	Auxiliary	Fuel Oil Equipment	Sequential Number
CALXX	Auxiliary	Lub Oil Equipment	Sequential Number
CAAXX	Auxiliary	Air System Equipment	Sequential Number
COPXX	outfit	Paint	Sequential Number
COJXX	Outfit	Joiner Linings	Sequential Number
CODXX	outfit	Deck Covering	Sequential Number
COFXX	outfit	Furniture	Sequential Number

[9] SHIP TYPE

CODE	DESCRIPTION
0	NOT USED
VLC	VLCC
COT	CRUDE OIL TANKER
PRT	PRODUCT TANKER
CHT	CHEMICAL TANKER
LNG	LIQUID NATURAL GAS
LPG	LIQUID PETROLIUM GAS
LBC	LARGE BULK CARRIER
HBC	HANDY SIZE BULK CARRIER
OBO	OIL/BULK/ORE CARRIER
CON	CONTAINERSHIP
ROR	RO/RO
CAF	CAR FERRY
PAF	PASSENGER FERRY
PAL	PASSENGER LINER
CRS	CRUISE SHIP
ACC	AIRCRAFT CARRIER
FLO	FLEET OILER
LHA	LANDING HELICOPTER ASSAULT
LSD	LANDING SHIP DOCK
LSC	LANDING SHIP DOCK CARGO VARIANT
CRU	CRUISER
DDG	DESTROYER
FRI	FRIGATE
SUB	SUBMARINE
MSH	MINE SWEEPER/HUNTER
MCM	MINE COUNTER MEASURE SHIP
PAB	PATROL BOAT

[10] INTERIM PRODUCT TYPE

CODE	DESCRIPTION
0	NOT USED
1	STRUCTURE
2	MACHINERY
3	PIPING
4	HVAC
5	ELECTRICAL
6	ACCOMMODATION
7	UNIT CONSTRUCTION
8	
9	

[11] INTERIM PRODUCT ATTRIBUTES #1 & #2

G	GRAND BLOCK	1	STRUCTURE

CODE	TYPE	NO OF BLOCKS
0	NOT USED	NOT USED
1	PARTIAL DEPTH PARTIAL WIDTH	2
2	FULL DEPTH PARTIAL WIDTH	3
3	PARTIAL DEPTH FULL WIDTH	4
4	FULL DEPTH FULL WIDTH	5
5		6
6		7
7		8
8		9
9		10

[11] INTERIM PRODUCT ATTRIBUTES #1 & 2 (Continued)

B	BLOCK	1	STRUCTURE

CODE	TYPE	GEOMETRY
0	NOT USED	NOT USED
1	SINGLE BOTTOM	3D PLANE
2	DOUBLE BOTTOM	3D CURVED
3	SINGLE SIDE	2D PLANE
4	DOUBLE SIDE	2D CURVED
5	DECK	
6	TRANSVS BULKHEAD	
7	LONGL BULKHEAD	
8	FLAT	
9	MAJOR FOUNDAT-ION	

[11] INTERIM PRODUCT ATTRIBUTES #1 & #2 (Continued)

A	ASSEMBLY	1	STRUCTURE

CODE	TYPE	GEOMETRY
0	NOT USED	NOT USED
1	SHELL	PLANE
2	TANK TOP	CURVED
3	FLAT	
4	DECK	
5	BULKHEAD	
6	EGG CRATE WITHOUT STIFFENERS	
7	EGG CRATE WITH STIFFENERS	
8	HATCH COAMING	
9	PACKAGE UNIT	

[11] INTERIM PRODUCT ATTRIBUTES #1 & #2 (Continued)

S	SUB-ASSEMBLY	1	STRUCTURE

CODE	TYPE	
0	NOT USED	
1	FLOOR	
2	GIRDER	
3	WEB FRAME	
4	DEEP BEAM	
5	BUILT UP SECTION	
6		
7		
8		
9		

[11] INTERIM PRODUCT ATTRIBUTES #1 & #2 (Continued)

P	PART	1	STRUCTURE

CODE	TYPE	
0	NOT USED	
1	PLATE	
2	SECTION	
3	FORGING	
4	CASTING	
5		
6		
7		
8		
9		

INTERIM PRODUCT ATTRIBUTE

P	PART	1	STRUCTURE	1	PLATE

CODE	GEOMETRY	MATERIAL	SHAPING
0	NOT USED	NOT USED	NOT USED
1	SQUARE	MILD STEEL	PLANE
2	RECTANGULAR	HY-80	FLANGED
3	TRIANGULAR	HY-120	CURVED
4	CIRCULAR	ALUMINUM	
5	CONTINUOUS CURVED		
6	2 STRAIGHT 1 CURVED EDGE		
7	>2 STRAIGHT 1 CURVED EDGE		
8	2 CURVED 1 STRAIGHT EDGE		
9	2 CURVED > 1 STRAIGHT EDGE		

[11] INTERIM PRODUCT ATTRIBUTES #1 & #2 (Continued)

8	PART	1	STRUCTURE	2	SECTION

CODE	SECTION TYPE	MATERIAL	SHAPING
0	NOT USED	NOT USED	NOT USED
1	ROUND BAR	MILD STEEL	STRAIGHT
2	FLAT BAR	HY-80	FLANGED
3	SQUARE BAR	HY-120	CURVED
4	BULB PLATE	ALUMINUM	
5	ANGLE		
6	TEE		
7	BUILT UP ANGLE		
8	BUILT UP TEE		
9			

[11] INTERIM PRODUCT ATTRIBUTES #1 & #2 (Continued)

8	PART	3	PIPING		

CODE	GEOMETRY	MATERIAL	SPECIFICATIO N
0	NOT USED	NOT USED	
1	PIPE	BLACK STEEL	
2	FLANGE	CRES	
3	90 ELBOW	ALUMINUM	
4	45 ELBOW	CU NI	
5	EQUAL TEE	COPPER	
6	REDUCER TEE		
7	REDUCER		
8	COUPLING		
9			

Stage

The code for the stages is alphabetic as follows:

Non-Construction Stages

Designing	DS
Planning	PL
Purchasing	PR
Material Managing	MM
Testing & Trialing	TE
Delivery	DL
Post-Delivery	PD

Construction Stages

Fabricating	FB
Sub-Assembling	SA
Assembling	As
On Unit Outfitting	OU
On Block outfitting	OB
Grand Block Constructing	GB
Erecting	ER
Launch	LA
On Board Outfitting	0 0

Work Type

The code for the work type is alphabetic and a sample is as follows:

Administration	AD
Operations Control	OC
Engineering	EG
Materials	MA
Material Handling	MH
Structure	ST
Pipe	PI
HVAC	HV
Machinery	MC
Electrical	EL
Hull outfit	HO
Unit Construction	UC
Joiner	JN
Paint	PA
Production Services	PS
Quality Assurance	QA
Test & Trials	TT

EXERCISE 3

CODING

ZONE DEFINITION EXERCISE

ZONE CODE DESCRIPTION

M XX ZZ Y

FIRST DIGIT IS THE FUNCTIONAL ZONE INDICATOR

S	STERN
M	MACHINERY
C	CARGO
B	BOW
W	SHIP WIDE

SECOND THROUGH FIFTH DIGITS - NUMBER XX ZZ Y

XX	LONGITUDINAL LOCATION	01 FORWARD MOST
ZZ	VERTICAL LOCATION	01 LOWEST
Y	TRANSVERSE LOCATION	0 CENTERLINE - ODD STARBOARD AND EVEN PORT

NATIONAL SHIPBUILDING RESEARCH PROGRAM

DESIGN FOR PRODUCTION IN BASIC DESIGN

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
One World Trade Center, Suite 1369, New York, N.Y. 10048
Spring Meeting/STAR Symposium, Portland, Oregon May 20-23, 1986

Design for Production in Basic Design

No.20

Thomas Lamb, Member, Bell Aerospace Textron, New Orleans, LA

ABSTRACT

"Design for Production" is a familiar term to present day ship designers. It takes into account production methods and techniques which reduce the production work content, yet meet the specified design requirements and quality. To some designers, this may appear as the basis of any good design! However, it is obvious from the current interest in the design for production approach, that this is not the general case today. Basic Design covers all design from conceptual through to the start of Product Engineering. However, in some shipyards, they only become involved in the interface of detailed design prepared by a design agent. It is then too late to try to incorporate design for production. Ship designers cannot effectively design for production without knowing how the ship will be constructed. Therefore, the principal problem for Design for Ship Production is the development of this knowledge for the designer. This paper discusses how this can be accomplished.

INTRODUCTION

Notwithstanding the fact that all engineering should be prepared to be the best for production, while meeting all the shipowner's requirements for quality, service and maintainability, and thus be the most cost effective, it seems that ship designers have not accomplished this as they prepared recent ship designs.

It is possible to obtain significant increases in productivity in existing shipyards without large investments in plant by redefining the ship design approach and planning the ship construction at the same time as the contract design is being prepared, thus being able to influence the design to suit the Intended building approach. This demands that ship designers become more production conscious as they design future ships. Design for Ship Production is really Design for Minimum Cost of Ship Production. This is accomplished by using the most efficient methods of construction while satisfying the many compromises resulting from the conflicting requirements between the shipowner, regulatory and classification rules, and the need to be competitive with other shipyards. The need is obvious and it should not have been necessarY to develop a new "science- to achieve it. However, it seems that ship designers have not, in general, changed with the changes in ship production and satisfactorily responded to the new needs. Many ship design groups continue to work in isolation from shipyard production influence and do not take into account the producibility of their designs. It has been suggested by a number of sources that this has occurred in the U.S. because almost all contract design and most detailed engineering has been, and still is, prepared by design agents and not in-house engineering departments. When a design agent prepares a ship design for a shipowner, it is probable that no shipyard will have been selected to build it. It is therefore, difficult for the design agent to include production aspects into the design that will satisfy the eventually selected shipyard. This is most unfortunate, as it is at this stage in the overall ship design and production process that the cost is being established and where there is the greatest opportunity to favorably, and vice versa, affect it. This is clearly seen from Figure 1, which shows that as the process moves from design into engineering, then planning and actual construction, the ability to influence cost, and therefore achieve cost savings, diminishes.

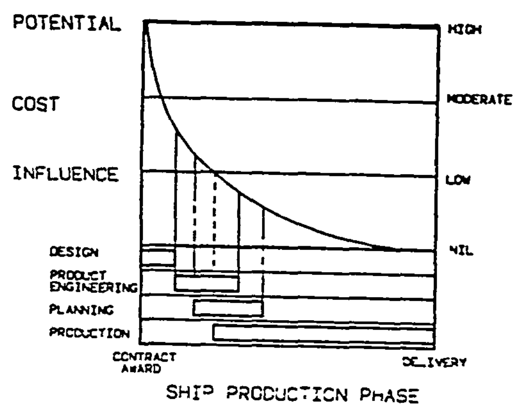


Fig. 1 Potential Cost Influence as Design and Production Progresses

It is therefore, essential that in the U. S., design agents develop a way to correct the current lack of production considerations in their designs for all future contracts in which they are involved. At the start of any contract design they should find out from the customer the shipyards that will be invited to bid for the contract and to spend time with the planning and production staffs of these shipyards to develop an understanding of their facilities, planning and preferred construction approaches and any standards developed by the shipyards. A big problem that must be solved by design agents, is the lack of shipyard and, more specifically, ship production experience of many of their staff. It will be necessary to develop some innovative ways for such inexperienced staff to obtain the necessary experience.

DESIGN FOR PRODUCTION

Design for Production, as a term, has been in use in Production Engineering since the late 1950's, where it applied to the linked functions of product design and process design (1).[1] The product design covered the preparation of the engineering information that defined the product. The process design covered the development of the production plan. Therefore, as originally conceived, Design for Production covered not only the design of the product, but also the design or selection of tools, methods and production sequence for least cost. Design for Production is the correlation of product design with the available or planned facilities and production methods. As such a designer could not perform well at it without knowing or being advised as to how the design would be produced. To accomplish this, the ship designer must become better educated in ship production processes and their relative costs. More recently, Design for Production has been defined as the deliberate act of designing a product to meet its specified technical and operational requirements and quality so that the production costs will be minimal through low work content and ease of fabrication and assembly. It is simply addressing the fact that today's ship designers have a commitment to assess their ship designs for high productivity. To do this, they must consider the relative efficiencies of available production processes and construction methods. This places additional responsibility on the designer. However, it must be willingly accepted, because if it is not, the effect on production costs can be fatal to a shipyard. Today's ship designer has both the opportunity and the obligation to design production oriented ships. This opportunity cannot be seized by the ship designer in isolation. It is only possible through an awareness of the shipyard facilities and methods used in the shipyard that will build the design. This necessitates continual interface and cooperation between the engineering, planning and production departments. The principal problem for Design for Ship Production is the development of this knowledge for the ship designers. This can be accomplished by the development of SHIPYARD SPECIFICATIONS for each shipyard and BUILDING PLANS for each ship to be built Ship designers constantly refer to the ship's Contract Specifications for the technical and quality requirements of the ship. It is suggested that they should likewise refer constantly to the Shipyard Specifications and the Building Plan for how the ship is to be constructed and to design accordingly. Table I is a subject listing of a Shipyard Specification and Table II the same for a Building Plan. More details on both can be found in (2). While the Contact Design was progressing, the Building Plan would be developed in parallel. The completion of the design during the Functional Design phase must obviously be in accordance with the Building Plan.

TABLE I

SHIPYARD SPECIFICATIONS

1.0 Facility Description
2.0 Facility Capacity
3.0 Organization and Responsibilties
4.0 Work Practices
5.0 Standards

TABLE II

BUILDING PLAN

1.0 Ship Description
2.0 Regulations & Classification
3.0 Contract Requirements
4.0 Construction Data & Quantities
5.0 Building Budget
6.0 Building Schedule
7.0 Build Strategy
8.0 Product Engineering

Obviously, the Building Plan follows the Shipyard Specifications, but details its application for a specific design. It should define module- boundaries,-assembly and module construction sequence, module erection sequence, extent of advanced outfitting, zone definition and building schedules. From this the engineering department would develop its drawing list and preparation schedule. The Buildinq Plan must be developed through input from both production and engineering personnel with adequate overall, as well as detailed knowledge of ship design, detailed engineering, product processing, assembly and erection.

Two recent papers (3 6 4), by the same authors, on Ship Structural Design for Production, state that its application is ineffective without a meaningful merit factor and that such a factor must be based on a production costing technique capable of takinq into account different physical design differences as well as production processes. While much can

[1] Numbers in parentheses designate references at end of paper.

be gained from the intuitive approach by knowledgeable and experienced designers, with and without input from planninq and production, it is still subject to differences of opinion, and the danger of errors of omission. That is, some aspect, process or work task can be left out of the consideration. It would obviously be better to use an industry, or at least, a company, accepted Merit Factor for the basis of the analysis.. Unfortunately, there is no merit factor currently available, and it is only necessary to try to discuss this matter with an experienced ship construction estimator to appreciate the extent of this problem. Ship Cost Estimating systems do not consider the design or construction tasks in sufficient detail to be able to be used as a Design for Ship Production Merit Factor. For example, for structure the cost estimating system may use combinations of total ship or module steelweight, complexity factors, average weight per unit area and joint weld length. These are not enough for a merit factor that will allow changes in detail to be compared. What is required is a method that takes into account " all the design and production factors that can differ. At the present time such a method does not exist, nor is there an existing historical data library from which it could be developed. It is therefore, necessary to develop an approach, and then collect the data required to use the approach. This is where the application of Work Measurement and Method Study techniques can help. One effective way to develop a suitable Merit Factor is to collect a quantity of related data, and apply Regression Analysis to obtain an equation fitting the data. The data can be obtained from actual case studies, deliberately selected to cover all the related design and production factors, and in sufficient different combinations so that the equation can be solved. Then a trial period is necessary where other case studies are chosen, and the derived equation used to predict the work contents. These are compared with the actual results of the new case studies and refined as necessary.

From the above description, it should be obvious that what is proposed is not a simple exercise. Significant effort would be involved as well as the potential to interrupt normal work in a shipyard. Nevertheless, it is necessary that the approach be completely developed If full benefits are to be obtained from the use of Design for Ship Production.

This has been attempted by J. Wolfram (5), for welding manhours In a shipyard panel shop. The resultlnq equation is:

$$\text{Welding Manhours} = 2.79 \times NPS + .0215 \times JLFB \times t_{FB} + .097 \times JLCB \times t_{CB} + .017 \times JLF \times FCSA$$

where NPS is number of panel starts
JLFB is joint weld length of flat panel butts
t_{FB} is thickness of flat panels
JLCB is joint weld length of curved panel butts
t_{CB} is thickness of curved panels
JLF is joint weld length for fillet welds
FCSA is cross sectional area for fillet welds

The same approach could be used for all other shipbuilding processes with the final system becoming an effective labor estimating tool for both new construction cost estimating and trade-off analysis. Until such an approach is fully developed for all processes, a less precise but similar approach could be used by applying known data and "guesstimates" to the various design and production factors for each design alternative. Fiqure 2 shows a form that can be used to perform a manual calculation for work content and cost for a structural part. Similar **forms** would be used for sections, sub-assemblies, assemblies, modules and the erection and joining of the modules. Obviously, the calculation could be programmed and run on a computer, and it is even feasible to link the computer program with an interactive computer graphics system which would present the desired merit factor for each design detail, as it was developed. Similar forms, or programs, could be developed for all other ship systems and production processes. "

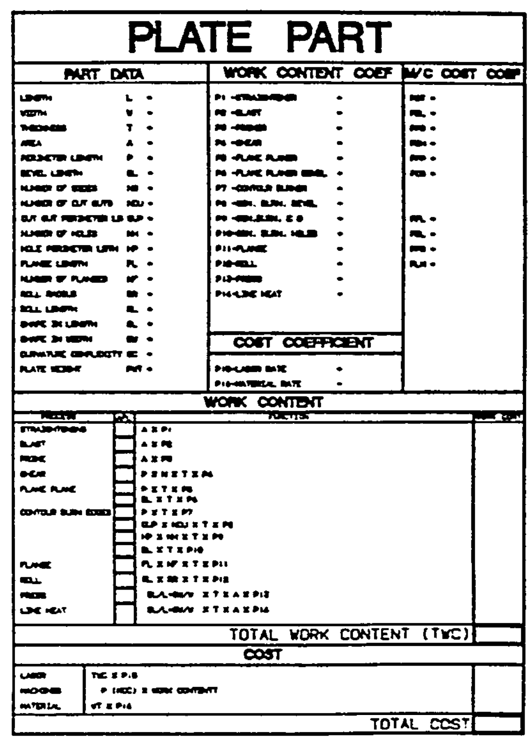


Fig. 2 Structural Part Work Content and Cost Calculation Form

Design for ShiP Production can therefore be applied in a number of ways, varying from a simple ease of fabrication "gut feeling" decision to a very detailed analysis using work measurement and method study techniques. The latter are considered the domain of Industrial Engineering, but a good understanding of them will improve the ship designer's ability to prepare the best production oriented designs for a given shipyard.

Most ship designers will not have either the experience or the time to use such techniques in their normal design decision process. However, if an Industrial Engineering capability exists in their shipyard, they should take every opportunity to benefit from it. If possible, they should work with the Industrial Engineers to arrive at the best design for their shipyard. If such a capability does not exist in the shipyard or it is too busy with the many other areas they are involved in, and it is not re-oriented by management, Design for Ship Production can still be performed. The ship designer with a team from planning and production can develop the different ways to desiqn a detail and rank them on the basis of producibility and cost aspects. When complete, the selected "best" design and the selection analysis can be sent to the other departments that are involved in the process, for their review and concurrence. It is strongly recommended that a Design for Ship Production team be established to review and maintain a shipyard's existing standards, and at an early stage of all new ship design development to ensure that the design will be the most producible and cost effective design for their shipyard. Table III is suggested as a minimum procedure for applying Design for Ship Production based on experience and intuition of such a team.

TABLE III

APPLICATION OF DESIGN FOR SHIP PRODUCTION

1. Examine Existinq Design
   a) Count the number of unique parts
   b) Count the total number of parts
   c) Count number, type and postion of joints
   d) Evaluate complexity of design
      Simple measurement
      Simple manual layout
      Complicated manual layout
      CAD/CAM applicability
      Required manual processing
      Required machine processing
   e) Producibility aspects
      Self-aligning and supporting
      Need for jigs and fixtures
      Work position
      Number of turns and moves
      Aids in dimensional control
      Space access and staging
      Standardization
      Number of compartments entered to complete work
2. Examine Alternative Design(s) in same manner
3. Select the Design that meets the objective of Design for Production, which is:

   The reduction of production cost to the minimum possible through minimum work content and ease of fabrication, while meeting the design performance and quality requirements.

BASIC DESIGN

Basic Design covers all design from Conceptual through to at least Contract Design. As used in this paper, it also covers Functional Design, which is the development of all design necessary after the award of a contract to define all systems and required material. This paper covers the application of Design for Production through Functional Design.

In some shipyards, the only design that they become involve in is "Detailed Design", such as working drawings for the shipyard and any calculations necessary to prepare them, which will be based on an owner provided Contract Design and Specifications. The subject of ship design is well covered in many books and in the transactions of the naval architecture and marine engineering professional societies. It will only be discussed to the extent necessary for the incorporation of Design for Ship Production.

The extent of basic design varies from shipyard to shipyard and, even in the same shipyard for different shipowl One shipowner may be quite specific abo~- what is required and present a very detailed Contract Design package. At the other extreme, the shipowner may simply state ship type, cargo deadweight, speed and crew size. Considerable effort has been expended by researchers and designers in developing computer programs which optimize the design characteristics based on a particular merit factor. Therefore, when computer optimizing programs are being used to design a ship for actual construction, it is essential that producibility aspects be considered in the program. For example, a particular shipyard may have building berth or dock limitations for length, breadth and draft; depth due to crane lift height and structural module size due to berth loading, transfer space or crane capacity. Fortunately, most optimization studies show that the proportions of an optimum design can be varied to suit building optimization with only slight detriment in the design optimization merit factor. Therefore, a design based on an operatinq optimization study, that is unable to include production details, should only be used to select major sensitive factors, such as speed, dimensions, draft and size. Then the design details should be selected for the shipyard, taking into accoup producibility factors while maintaini: the desiqn performance derived from th.

operating optimization relationship. If for some reason the shipyard designers find the speed/power relationship is wrong, then the operating optimization study should be rerun usinq the correct relationship to see if the optimum speed or size changes. Once the design characteristics are selected, it is necessary to marry every desiqn decision with Producibility decisions.

TAILORING DESIGN TO FACILITIES

While it is beneficial for a shipyard to be able to build any ship design, it is a well known fact that such general capability will increase the cost to build the shipowner's custom design than one which is designed to make best use of a shipyard's facilities. Obvious shipyard imposed requirements are:

- o Ship dimensions and limits
- o Module maximum weiqht
- o Module maximum size
- o Panel maximum size
- o Panel line turning and rotating capabilities

Obviously, a shipyard would be unwise to attempt to build a ship which was longer or wider than the building berths and/or docks, or hiqher than the cranes could reach. Of course this would not be so if part of the building plan was to improve the facilities.

The module maximum weight can be dictated by berth or shop crane capacity, and/or transporter capacity. Also, by advanced outfitting and any temporary bracing and lifting gear used for the lift. The module maximum size will depend on access throughout the shipyard for the modules from assembly to erection, shop door sizes and the shipyard's maximum plate size. The panel maximum size will depend on panel line limits as well as any access limits. It will also be impacted by whether the panels need to be turned and/or rotated. A panel line with no rotation capability can achieve the same results by vertical plate strakinq of shell and bulkheads when the ship is transversely framed and the bulkheads vertically stiffened.

Not so obvious and often ignored requirements are:

- o Maximum berth loadinq
- o Spread of launchways
- o Maximum launch pressure on the hull

The maximum berth loadinq could affect the extent of outfitting before launch and thus the productivitv achieved in building the ship. Heavy concentrated weights, such as propulslon engines and gears, and independent LNG tanks may not be able to be installed until the ship 1s afloat. The spread of the launchwavs should be matched by basic shlp's structure, such as longitudinal alrders, in order to elimlnate the need for any additional temporary strengthening, which only adds to the work contest. Likewise, the structure of the ship in way of the area subjected to maximum way end pressure and the fore poppet should be designed to withstand these loads without the need for additional temporary structure.

Whatever the facility requirements on the desiqn, it is obvious that they must be fully industrial engineered, well documented and communicated to the designers. The use of computer simulation techniques on interactive terminals(5) can serve as both an educational and informational tool.to give ship desiqners a better understanding of the capabilities of a shipyard. The already stated concept of a Shipyard Specifications of parallel importance and applicability as the usual Contract Ship Specifications would also be an effective way to accomplish the transmission of the information to the ship designers. However, it would not in itself assure production oriented designs. To assure this, it is essential that the ship designers be educated and trained in the field of Design for Ship Production.

ARRANGEMENT DESIGN

When developing the arrangement of a ship, decisions must be made regarding the location of cargo tanks, machinery spaces, holds, tanks and their contents, number of decks in the hull, number of flats in the machinery space, cargo handlinq qear type and capacity, accommodation layout etc. It is therefore, obvious that the development of the arrangement of a ship has a significant influence on its total construction work content. Yet it is usually performed with minimum production input. The construction work content is greatly affected by design decisions on the following aspects.

Stem

The bow of a ship is one of the areas where designers regularly incorporate reverse curvature, apparently, without any concern for its work content and thus cost. One only needs to look at a few ships to see this. Curved stems may be astheticly pleasing but their cost must be appreciated. Even slight departures from a straight line stem will add to the difficulty in fabricating it. The simplest above the water stem is one formed from a cone. This will give eliptical waterline endings, NOT circular, as most designers use. The only reason stem castings are used today is because the complexity of the design necessitates it.

Most ships can be designed without the need for concave waterlines in the bow. For ease of production, straiaht and convex waterlines are Preferable. In section, the frames in the bow are usually concave to provide dry foredecks and adequate deck area, but maintain vertical frames in way of the load waterline. This results in reverse curvature shell

plates. Even though plate forming by line heating enables complex shapes tc be processed without rolling and pressing, it is still additional work content compared to a single curvature plate.

Stern

The term stern usually covers two important independent but obviously connected items, namely the propeller aperture and the rudder arrangement; and the portion which is mostly above the design waterline aft of the rudder stock centerline.

The single screw propeller aperture has evolved from early counter stern combined rudder post types to the "open" or "Mariner" style with spade or horn rudders. The design approach tended to favor "closed" apertures to reduce the size of the rudder stock to the minimum. However, even though it results in the largest rudder stock, spade rudders have the least work content if properly integrated in the design of the stern structure, and modern bearings are utilized. This can be seen by comparing all the parts and the various work sequences involved in both approaches as is done In Figure 3.

The upper stern development proceeded from the counter stern to the cruiser and then transom. Merchant ship designers adopted the transom stern because of its obvious economy, but also as it maintained deck width aft which was important In deck cargo ships, such as container ships and ships with aft deckhouses. Unfortunately, designers still introduced aspects which cause additional work content for transom sterns, by sloping it in profile and providing curvature in plan view as well as large radius corner connection between shell and transom.

Hold or Tank Length

The frame spacing should be constant throughout the ship's length with the exception of the peaks where the usual practice of incorporating smaller spacing is required by classification society rules. In the case of bulk carriers anc general cargo ships, some designers deliberately varied the lengths of the different holds and tween decks to equalize the loading and unloading times (7). It is suggested that the length of the holds or tanks should be constant throughout the ship so that they can be divided into standard structural modules and then simply duplicated as required. For example, in a ship with five holds of which three are in the parallel body and each hold has four modules, then only four different structural module drawings need be prepared for three holds. If on the other hand the hold lengths are all different, then twelve structural module drawings are required. When the standard hold concept is carried over into lofting, process planning and actual construction, the labor and time savings multiply quickly. This approach is simply applying Group Technology on a macro level during Basic Design, thus ensuring it can be utilized at the micro level during Product Engineering, lofting, processing and work station manufacturing. If it is necessary to vary the length of some holds or tanks, the length should be one or two web frame spaces more or less than the standard length so that the standard drawings can be simply extended to the non-standard length.

Engine Room Location

In small ships the engine room can be located anywhere in the length that provides a workable loading/trim relationship for the intended operations.

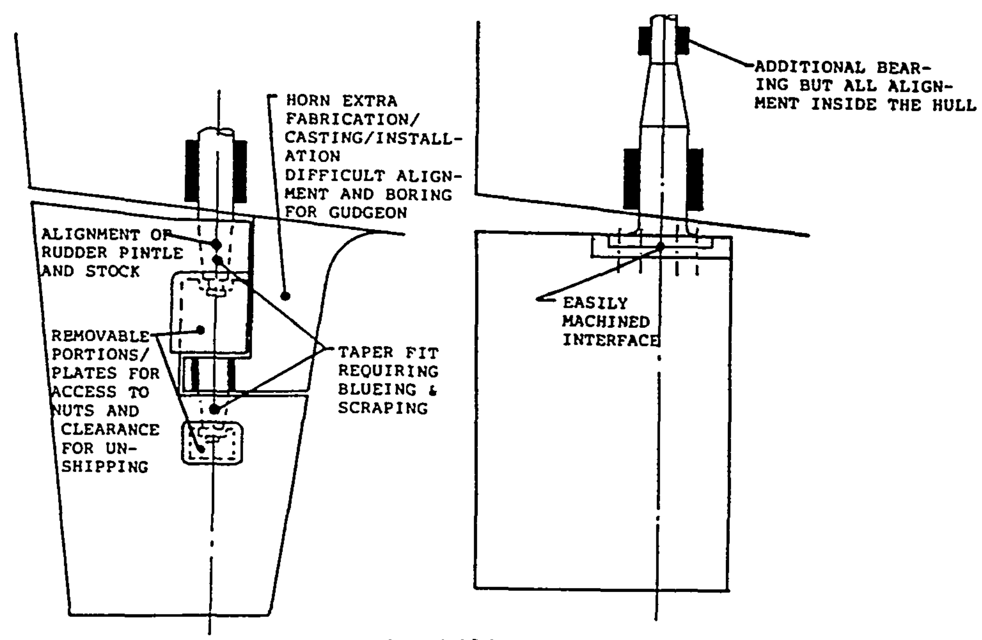


Fig. 3 Rudder Type Selection for Producibility

For large ships the engine room Is usually located aft of amidships. A popular location for the engine room in cargo ships is the two thirds aft position **(8).** In all cases the obvious producibility factors to consider are:

o Length of shafting
o Engine room is not suitable for standardization of arrangement and structure. Therefore, the engine room should be located in the part of the ship least suitable for standardization, that is, the ends.
o A shaft tunnel or alley is needed except for the all aft location.
o An all aft deckhouse requires more tiers to provide adequate line of sight over the bow.

Before the recent skyrocketing increase in fuel cost, a number of novel machinery arrangements were developed, usually for novel ships, but sometimes for traditional ships such as tankers and bulk carriers. They were proposed for both reductions in material and operational costs as well as ease of construction. Some of these which impacted productivity were:

o Split engine rooms above main deck with azmuthing propulsory.
o Propulsion engines in twin skegs.
o *Gas* turbine/electric with GT generators above main deck.

Machinery Arrangements

It is essential that producibility be adequately considered during the development of the machinery arrangement, not only in the equipment layout but for the surrounding structure. This can best be illustrated by an example. Figure 4 shows a typical large naval ship machinery arrangement consisting of two main machinery rooms and a central control room. The ideal, from a producibility point of view, is that both machinery arrangements should be identical. The next best is to make the arrangements mirror images about the centerline of the ship. Obviously, only the aft space has two shafts in it. The forward space should simply be a mirror image of' the aft space with the transiting shaft deleted. This is only possible if the shafts are parallel to each other and are horizontal. Unfortunately, this is often not possible, and the different spread angles anti shaft slopes prevent exact mirror image spaces. Even In this case, the machicery; **rooms** can still be mirror images except for the propulsion machinery setting.

The mirror image requirements also apply to the surrounding structure as well as the machinery and equipments. It can be seen from, Figure UZ; that the duplicity of arrangements in the machinery rooms and surrounding stronger was not attempted. The following differences can be noted;

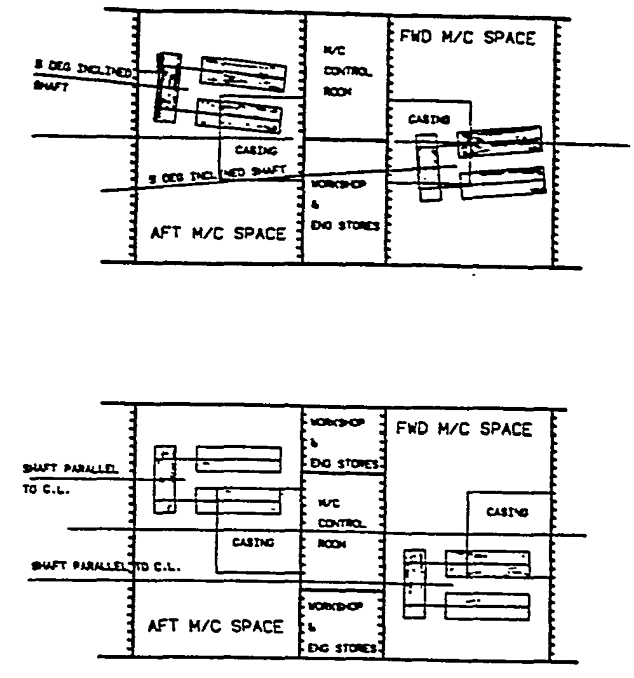


Fig . 4 Machinery Room Arrangement Design

0 The aft transverse bulkhead in each room is different, one flush the other has stiffeners.
0 The same as above for the forward bulkheads.
0 The casing is aft in one room and forward in the other.
0 The control room is oriented different to each room.

Figure 4b) shows the same spaces with the arrangements developed to minimize necessary design, lofting and installation work content by incorporating duplicity as much as possible. It should be noted that the control room is now in the same relative transverse location for each room, but obviously it is not longitudinally.

The layout of the auxiliary machinery has a major producibility impact, and, therefore, it is important to arrange it in the most effective way. Today that means equipment package units, piping/grating units and advanced outfitting. This is because advanced outfittlng is driven by labor and schedule reduction goals, such as straight lengths of pipe, right angle pipe bends and combined distributive system/grating support units, all of which are manufactured in Ideal shop conditions. However, the basic requirement in the design of engine rooms is the ease of machinery plant operation and maintenance and must be net and not impared, regardless of the method of design and construction. Forturate, the procedures used for developing advanced outfitting design. are compaticle with this basic requirement. If it is attempted to lay out auxiliary machinery

during Basic Design, It must be determined If advanced outfitting of the machinery spaces is Intended as certain approaches must be followed If it is. Even if advanced outfitting 1s not intended, it is still good design to approach the arrangement of machinery spaces Into associated equipment groups and service corridors or zones. It iS suggested that only the unit boundary need be shown and the equipment within each boundary listed. If the ship designer does not take such matters into consideration and prepare production oriented Contract Machinery Arrangements, It is strongly suggested that the document they prepare be designated as a Contract Guidance drawing, and only be used to show required equipment and any preferred layout.

Cargo Hatch Sizes

Standardization is the major producibility goal that should apply to cargo hatchways and hatch covers. All cargo hatches should be identical on *a* given ship or size of ship for a given shipyard. This would allow hatch coamings and covers to be designed and lofted only once, and to be built on a process flow basis. In addition to size and detail, the location of the hatches relative to the hold transverse bulkheads, should be identical. The module erection sequence must also be decided at this stage as it will obviously affect the design, and, in turn, the work content for the hatch module and its installation. This can be seen from Figure 5 which details two possible design approaches that could be used.

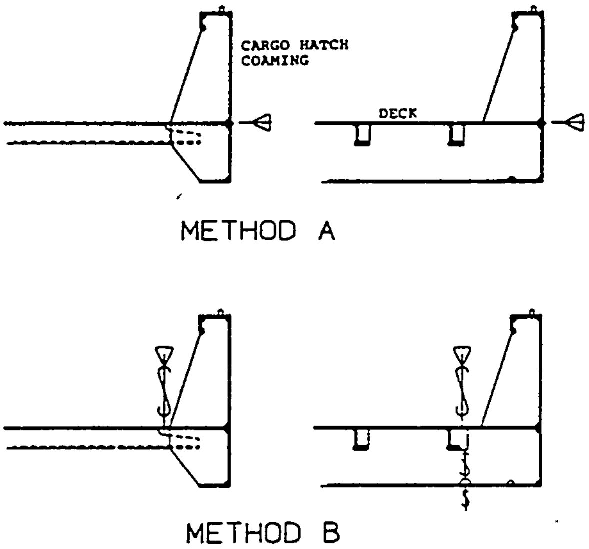


Fig. 5 Hatch Installation Alternatives

Method A shows a hatch coaming that would be erected on top of the deck. It usually requires "stock or green" material to be left on the lower edge of the coaming for scribing to the deck. Also, the fillet welds of the coaming to the deck are not suitable for machine welding due to the brackets on the outboard side, and no work surface for the machine on the inside. It will be necessary to provide staging inside the hatch coaming for the workers weldirg the inside fillet. Method B incorporates part of the deck in the hatch mdule. Any "stock" material would be left on the outboard deck and the hatch module easilly fitted by using the deck edge on the hatch module as a burn in guide. It should be obvious that Method B allows machine welding of the deck scan and butt on top of the deck. Staging would still be required for the fitting of one sided welding tape, if used, or for the overhead welding below the deck, but it would be easier to erect and dismantle from the tween deck below.

Double Bottom Height

The height of the double bottom is usually derived from the appropriate classification rule depth for the center vertical keel. Most double bottom spaces are small with difficult access for both workers and their tools. A problem often results from deciding the double bottom height based on the midship section shape. The bottom shape rises both forward and aft of the midship section, and this reduces the height in the double bottom outboard. Therefore, it is necessary to consider double bottom height at the location where the hull shape reduces it to a minimum at the ends of the inner bottom extent. It is possible to use a smaller double bottom height with transversely framed ships than with longitudinally framed ships . This is because for longitudinal framing, the transverse plate floors need to be deeper to allow for a reasonable distance between the cutouts and access holes. This is shown in Figure 6.

Tween Deck Height

The tween deck heights may be decided by an operational requirement, such as use of standard pallets, hanging refrigerated meat, maximum number of boxes that can be stowed on top of each other, carriage of containers, RO-RO cargo, etc. in such cases the deck level must be selected to allow cost effective design of ship structure.

In way of accomadaticn spaces, the tween deck height should be selected to allow high. productivity installation of the overhead vent ducting, piping and wiring. If it is difficult for the designer to squeeze such systems into the allowable space, it will be many times more difficult and use higher man hours for the worker to install the systems. It is usually possible to select a smaller tween deck height in accommodation spaces with transverse beams rather

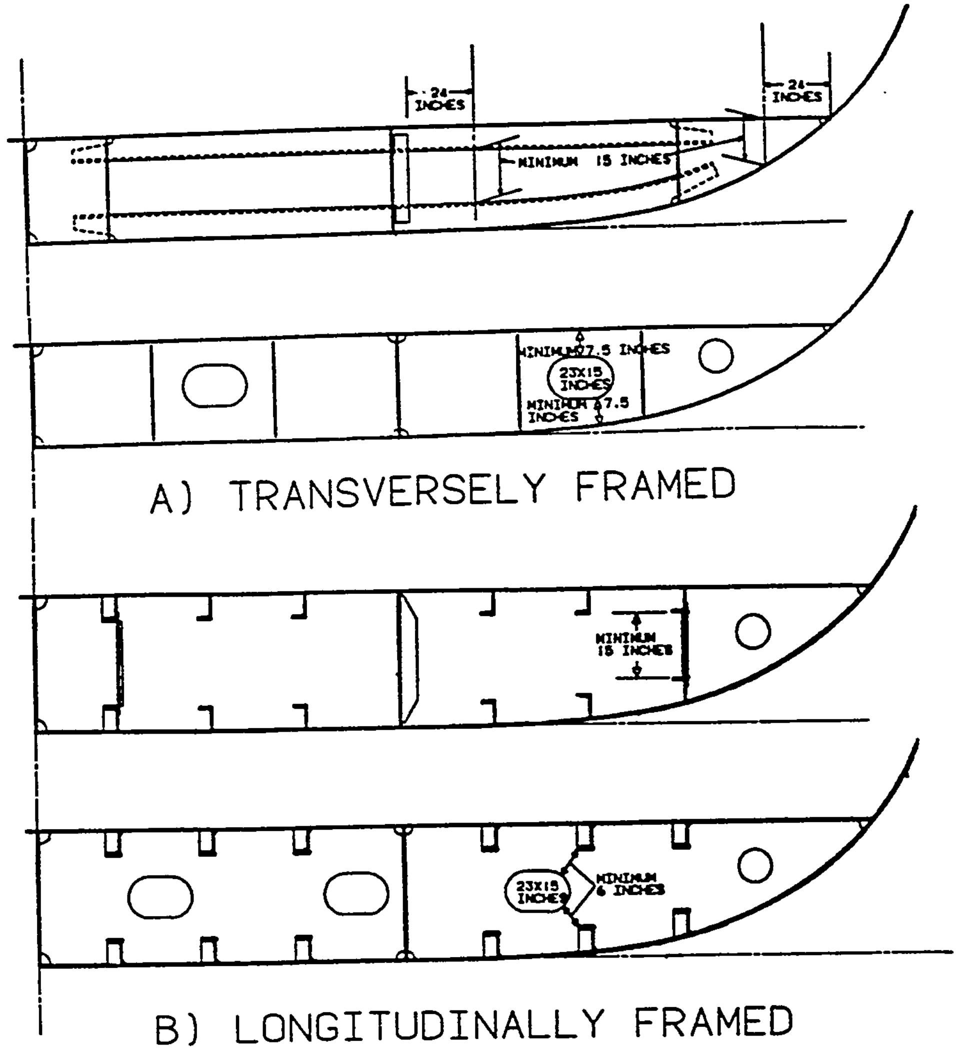


Fig. 6 Factors Affecting Double Bottom Height

than longitudinals. This is because longitudinally framed deep deck transverses add to the required height for fore and aft run services. Conversely, if the deck is longitudinally framed, additional tween deck height should be provided. This requirement can be seen from Figure 7. When the tween deck height must be kept to a minimum, it may be better to provide deeper deck transverses or non-structural steel bulkheads, and run the systems through them at a constant height rather than work to the minimum depth for the transverses and running the systems below them. Another possible approach, which is applicable to modern construction methods, is to select zones over service areas, passageways and toilets, and provide only the allowable minimum clear deck height in way of the zones. The specified clear deck height is maintained in all other areas.

Use of Corregated and Swedged Stiffening

One very effective way to reduce work content as well as the weight of the structure of a design, is to use corregated and swedged stiffening for

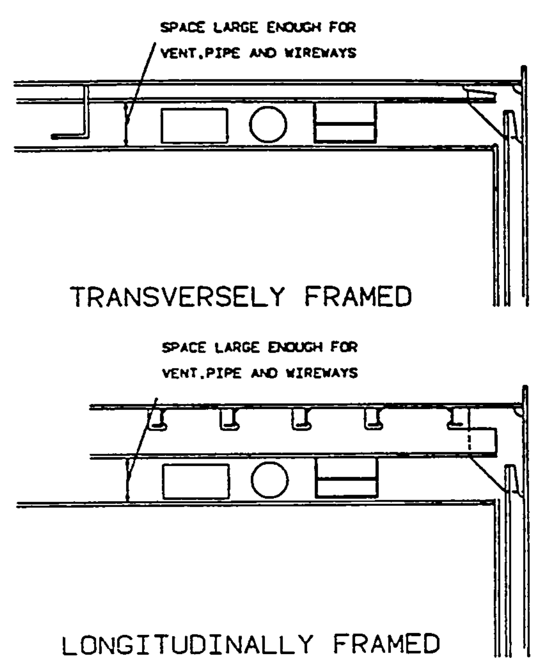


Fig. 7 Required Space for Services

bulkheads, deckhouse decks and sides. The work content is obviously reduced due to the reduction in the number of parts to be processed and assembled, and joint weld length, but it is also due to the elimination of weld deformation of thinner plate. There is an increase In work content due to the forming effort, but the net result is a significant work content reduction.

Correlated bulkheads can be effectively integrated with acoess ladders, pipe corridors, space ventilation and other Items passing through the space. Correlations for transverse bulkheads could be either vertical or horizontal, but for longitudinal bulkheads they must be horizontal.

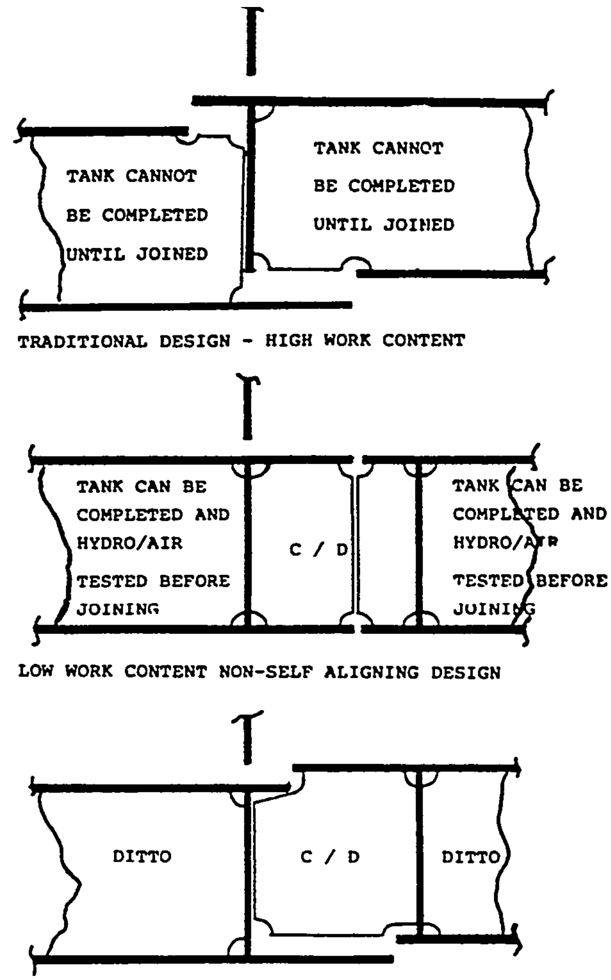
Swedged bulkheads can be used for tween deck structural bulkheads, and for all miscellaneous non-structural steel or aluminum bulkheads. Swedges must be vertical. Swedged stiffening could also be used for decks inside deckhouses. For short deckhouses with no influence on the ship’s longitudinal hull girder strength, the swedges could run transversely. For long deckhouses, the swedges should run longitudinally. The decks would be swedged downwards and the trough formed by the swedge filled with deck covering underpayment.

One disadvantage of correlated and swedged construction is that it prevents machine welding of the edges perpendicular to the correlations or s-wedges to the connecting structure. This can be overcome by developing welding machines especially for this purpose, and in the case of swedges, by modifying the ends so that the intersecting edge is flat.

Location of Tank Bulkheads

From a production point of view, it would be ideal if the tanks in each erection module could be completed and tested before erection. This would enable any defects to be easily corrected on the module construction platens. This is not psssible when common tank boundaries cross or are located at erection joints. Usually, only a portion of the tanks need to be hydraulically tested, and then the erection joints should be located in the tanks that will not be hydraulically tested. In addition if che tanks are to be coated, it would be preferable to have no module connecting ‘welding which would damage the coating thus requiring rework.

improvement depending on the design, extent of required testing’and tank coatings. Figure 8 shows this concept. Obviously there could be some coating damage where the bulkheads are welded to the tank top, but this can be avoided b incorporating a strip of bulkhead onto the tank top before the tanks are coated. It could also be solved by increasing the cofferdam size to two frame spaces, but this may be unacceptable for a number of reasons.



LOW WORK CONTENT SELF ALIGNING DESIGN

Fig. 8 Module Joining Productivity Considerations

Deckhouse Shape and Extent of Weather Decks

Sloping house froms, exterior decks along the sides and aft bulkhead, and sweeping side screens all add significant work content to the task of constructing a suitable dechhouse to accommodate the arew, and provide the necessary operating and service spaces. While certain skips such as passenger and cruise ships can justify the additional cost of such aesthetic treatment, in general, they are unessary additional work content for all other types of ships. They not only increase the construction cost, but they also cost

more to maintain during the ship's operational life. The ship designer should develop simple deckhouse design utilizing vertical and flat deckhouse fronts, and only provide exterior decks that are required for the safe access and working of the ship. Figure **9** shows the two extremes. and the additional work content can be clearly seen.

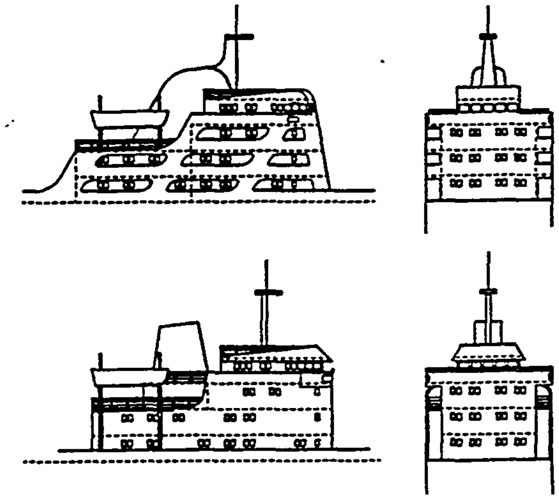


Fig. **9** Aesthetic versus Cost-Effective Deckhouse Design

Sheer and Camber

Eliminating sheer and camber results in a flat deck which has less work *content* than a deck with both. This is due to eliminating the need to form the decks, the deck beams, angle the deck beams and form the deck girders. This applies to decks In the deckhouse and superstructure as well as the hull. For some designers and owners the elimination of sheer and/or camber is a very emotional matter and they argue that it improves the seakeeping and other operational aspects of the ship. The other side logically argue that this Is not the case because ships are seldom level when at sea, and even in port they usually have trim and list.

Access for Workers and Equipment

The arrangement designer must consider how the ship will actually be constructed, and provide adequate access and working levels, including permanently built-in solutions, for workers ard their equipment during the construction and later maintenance of the ship. Some ideas in this regard are:

- o Service trunks, corridors or zones for deckhouses and above machinery spaces.
- o Cofferdam under deckhouses that will be constructed and outfitted completely before erection, on the hull *or* between two module of a deckhouse erected in two tiers.
- o Galleries in tankers which eliminate need for staging.

Effect of Admeasurement Rules

The application of the U. S. Admeasurement Rules has adversely affected the producibility of structural design for many years. Access holes in double bottom floors and girders, and to tanks have been restricted to **23** by 15 inch ovals. Lightening holes have likewise been restricted to 18 inch diameter, except in fuel tanks where 30 inch diameter holes are allowed providing they are "strapped" by installing a **3** inch wide flat bar horizontally across the middle of the hole. This is an obvious work content increase that has no real design function. In the U. S., for small ships that benefit from being measured below 200, 300, 500 and 1600 *Gross* Registered Tons, various admeasurement reduction devices such as full depth plate floors on alternate frames, tonnage openings in cargo and accommodation spaces, and excess capacity of water ballast tanks all add significant work content to the ship. The 1969 IMCO Tonnage Convention will eventually eliminate the unproductive additional labor and material cost for the *larger* U. S. built international voyage ships, as it does not allow any of the admeasurement reduction devices. However, the old practice will probably be continued indefinitely in the U. S. for small *domestic* voyage ships, thus perpetuating the additional work content and material. By eliminating the tonnage reduction devices in larger ships, the ship designer will be free to utilize access and lightening holes to suit the shipyard's best approach to access for workers, equipment and material.

It is imperative that the arrangement designer be fully aware of the admeasurement method to be applied to the ship, and if it is the "new way", to erase all "traditional" tonnage affected design details from the ship arrangement, and utilize instead details that improve productivity.

LINES DESIGN

As already stated, a Lines Drawing developed without consideration of the impact *on* production of its various work content aspects, can increase the work content significantly, and prevent the achievement of high productivity and lowest construction cast. clipper bows, *cruiser* sterns, double and reverse curvature surfaces, keel, stem and stern half sidings, and inappropriately located knuckles/chines; all add work Content.

The development of low resistance and efficient propulsion lines is a highly specialized field and often is performed by naval architects and hydrodynamicists with very little shipyard engineering and production experience. While it is not proposed that consideration of the producibility aspects be allowed to over-

rule the lines designer's decision where it could adversely affect the efficient operation of the ship after it is delivered, it is proposed that lines designers should obtain a better understanding of the impact their design decisions have on the producibility of the ship. They should then incorporate producibility improvement aspects which have a high work content reduction. and a small, if any, adverse impact on hydrodynamic and propulsion efficiency. In this context, it should be remembered that a seagoing ship hardly ever operates in smooth water, and that the impact of any producibility change should be considered in its seagoing environment, and not the result of a smooth water model towing tank test. Therefore, when preparing a lines drawing, the following items must be considered from *a* producibility point of view:

Stern

At one time most stern frames were designed as castings. This enabled complex shape to be incorporated in the design, and also to provide an early erected reference to build to when ships were constructed part by part on the building berth. The wide spread use of structural modules necessitated the integration of the stern structural design. Therefore, the ship designer must select stern lines and propeller aperture shape to enable the stern module to be easily constructed and eliminated the need for separate and cast stern frames.

Flat Keel

The width of the flat keel plate used to be a rule requirerment for most classification societies. Many developers of lines still use these standards as guidiance. For designs with rise of floor, the selected width becomes the knuckle in the bottom. This approach is not correct! The width of the flat keel should be at least wide enough to extend over the keel blocks to allow for welding'of *one* of the seams as an erection seam when the modules have a longitudinal break along the center of the ship. Where the bottom module spans the blocks, this is obviously not a factor. It is suggested that two other aspects must be considered to decide the width of the flat keel. The first is that the shipyard maximum plate width should be used as the flat keel width. The second is that if one of the seams is used as an *erection*. joint,, the flat keel width' must suit the module joining method, including the design detail of the internal structure. These concepts are shown in Figure 10.

Maximum Section Shape

The design of the maximum section of the null considers bilga radius, rise of floor, and slope of sides. There is considerable guidance available

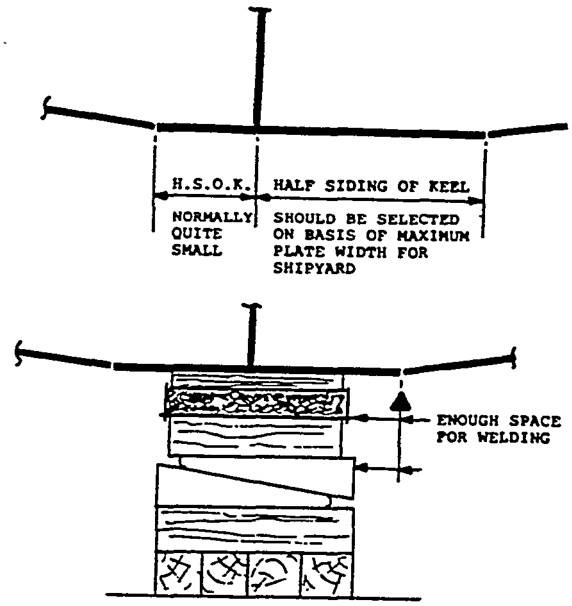


Fig. 10 Flat Keel Producibility Considerations

to the ship designer on the maximum section coefficient based on resistance aspects. Obviously, the required coefficient can be satisfied by a combination of bilge radius, rise of floor, and even sloping sides. The bilge radius should be selected so that the side module erection joint is above the tangent of the ship's side to the bilge radius, and above the tank top. In single bottom ships it may be preferable to select the bottom bilge radius seam as the erection joint and then the radius should suit this . The use of conic sections for the bilge shape as it moves forward and aft of the maximum section would result in the bigle shape being an ellipse and not a circle. This fact must be appreciated by the designer so that the intent to have circula sections can be correctly incorporated into the lines. If this is not done it may result in significant increase *In* work content as the shell plates must be formed to eliptical roll sets instead of a simple radius.

Brackets

The after body lines of a single screw ship are selected to provide low resistance and good flow to the propeller. Normal single screw aft bodies are another part of the hull where reverse curvature is found. This reverse curvature can be eliminated by carefully locating plate seams and butts at the transfer lines from convex double- curvature plates to concave plates. Even though double curvature plates have less work content than *reverse curvature* plates, the work content is still significant. One way to reduce the work content of the after body even further

Is to separate It into two parts, namely; the main hull and *a* skeg. This *can be* done in two ways. The first way Is to attempt to follow the normal single screw hull form as closely as possible by incorporating *a chine or* multi-chixes, joined in section by straight lines. The chines would lie in flow lines to prevent cross flow turbulence as much as possible. The second way, is to design the after body of a twin *screw* warship type, and add on a skeg. Both approaches can usually be used without any adverse impact on propulsion power. However, the latter approach has the least work content.

Bulbous Bows

From a producibility point of view, the preferred shape of the bulb in the transverse plane is a circle. This shape *can have some* operating disadvantages, such as bottom slamming in a seaway. Next preferred shape that does not have the slamming problem, is an inverted tear drop, but it has a higher work content than the circular shape. A good compromise between design and production requirements is an inverted tear drop constructed from parts of two cylinders, two spheres, a cone and two flats. A similar approach to developing producible details should be applied to other types of bulbous bows for large slow speed full hull form ships, such as tankers. Partial stem castings have been used for bulbous bows where they are faired into the upper stem and shell. The casting can be eliminated by making the bulb to shell connection a chine.

Knuckles and Chines

Many ship designers utilize chine hull form designs on the assumption that they are easier to build than round bilge forms. Although this is generally true for small ships, it is not always appreciated that chines can add work content to a design. Before discussing this further, it is necessary to understand the difference between chines and Knuckles. A formal definition of a chine is that it is the intersection of the bottom and side shell below the load waterline. However, it is usually used for any shell intersection curve, and in the case of double chine hull forms, reference is made to upper and lower chines. A chine is *always on the* shell and nowhere else. A chine is usually a curve in at least one plane. A knuckle can be anywhere on the ship. However, *a* knuckle is a straight line in two planes. Sometimes a chine located in the forebody above the load waterline is incorrectly identified **as** 2 knuckle because in profile it is a straight line. However, in plan view it is a curve.

When a chine is introduced into a design and it is curved in two views, it can present a problem if the snip iS constructed in modules, as the chine is *an* obvious module erection *joint. in* addition, a chine that crosses a deck line introduces additional work content due to construction design details, including varying frame lengths and additional frame brackets. Chines are often located to follow flow lines in order to minimize any resistance increase. However, It is better, from a producitilicy point of view, to located the chize parallel to the baseline/tank top/decks, as this enables the chines to be used as simple module joints and for simple alignment of the modules. It also permits standardization of design details for floors, frames, brackets,etc. These concepts are shown in Figure 11, which also shows the problems with current chine shapes.

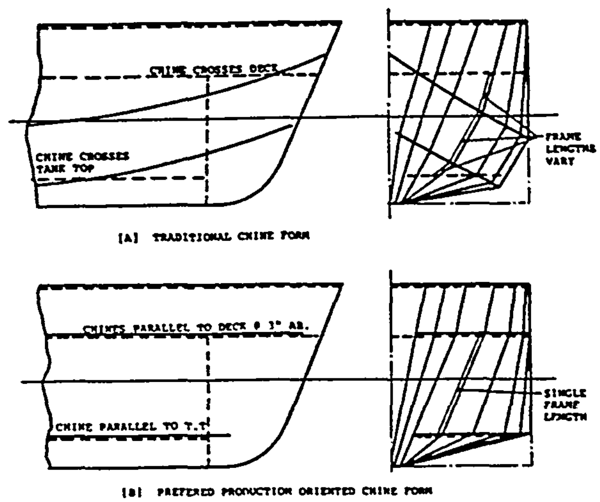


Fig. 11 Hard Chine Producibility Considerations

STRUCTURE

The design of ship structure is the process or applying rules and expedience to integrate individual structural components into efficient and easily constructed sub-assemblies, assemblies, modules and hull. Because it is *a large part* of the weight, construction manhours and material cost, and also as it is relatively easy to design, more details are usually *given* for the structural part Of a Contract Design than for any other discipline. Yet it is for the structure more than any other discipline that each shipyard must individually design. to suit their facility or else have its needs and preferences incorporated into the design *during* the preparation of are Contract Design. It is suggested that structure design, if prepared by a design. agent for a Contract Design, De designzated as “Guidance Only”, this.allowing the shipyard to utilize their o wn details. However, this has been prop-

osed before (9 and 10) and it has not resulted in any change by Design Agents and Owners. In this situation, it is important that designers realize the impact of their design decisions. Many ship structural designers use "Standard Structural Details", which they may have 'borrowed" from other designers in another shipyard. Or, for a naval ship, they. may simply use the old BUSHIPS Standards, which are over 20 years old. Chances are that the decision to use a particular detail will be made withbut any regard-to producibility requirements for the shipyard Involved. It should also be remembered that as there are a great number of connections between the structural components of a ship, the" best" design for One shipyard may not be the "best" for another. The 'best!! structural design detail depends on:

- o Module definition and erection methods
- o Manual versus computer-aided lofting
- o Manual versus N/C cutting
- o Extent of automatic welding
- o Whether or not the shipyard has a panel line
- o Facility and equipment

However, the basic goal of Design for Production is to reduce work content, and the development of structural details should accomplish this goal. Before discussing some details, it is necessary to consider the selection of module boundaries.

Module Definition

Although this aspect of planning and structural design appears to be reasonably handled by most U. S. shipyards, it is still possible to see module boundaries and structural details in way of the module breaks that are obviously not well thought out. When deciding module boundaries, a number of items must be considered, some obvious, and some not so obvious. These are:

- o O Maximum module size
- 0 Maximum module weight
- 0 Module turning limitations
- 0 Shell shape boundaries
- 0 Access for workers and equipment required for joining modules
- 0 Extent of use of auto and semi-auto machines
- 0 Whether *or* not self aligning
- 0 internal connection detail
- 0 Framing method
- 0 Flare straking direction
- 0 In. line or staggered transverse brears
- G Maximum or stazdard plate/shape sizes
- c Completion of adjacent scaces/tanks
- o Blocking or shoring requirements
- 0 Natural lifting points
- 0 Use of "green or stock" material for fitting
- 0 Large equipment arrangment and foundations to avoid overlapping module breaks
- 0 Design to eliminate plate or pin jigs

The module boundaries should be located at natural plate butts and seams. Module breaks should be located to minimize erection work content. For example, in a longitudinally framed ship, it would be better to have long modules, whereas for a transversely framed ship wide modules would be better. This iS because the above choices would eliminate section joints and leave only plate joints as can be seen in Figure 12.

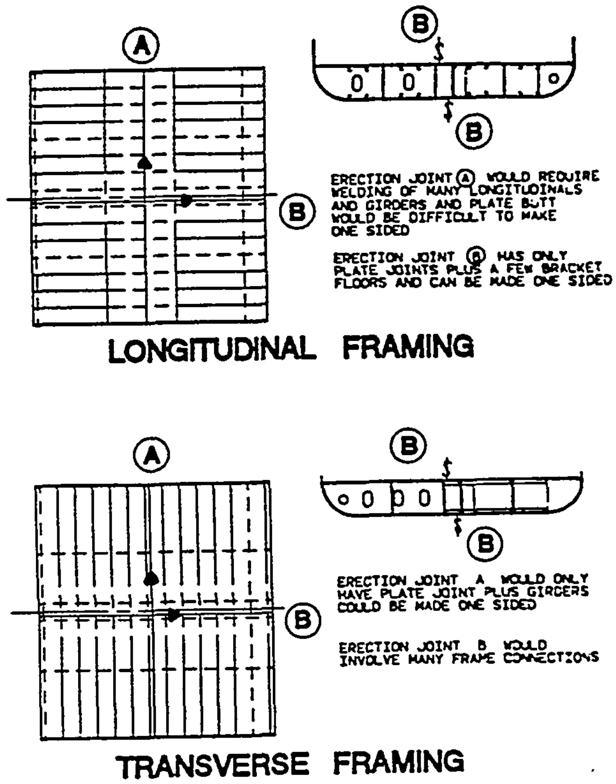


Fig. 12 Module Break Producibility Considerations

Structural Details

The labor man hours to construct the structure of a ship can be significantly reduced by proper attention to the design of the structural details. A number of structural details are --amined in this context.

Plate Straking

The obvious goal for plate straking is to standardize the plates. A standard plate should not only be identical in size, but also in marking, bevelling, etc. This can only be accomplished by

locating the stiffeners and webs/floors In the same position on each standard plate. To do this, two options are possible as shown in Figure 13.

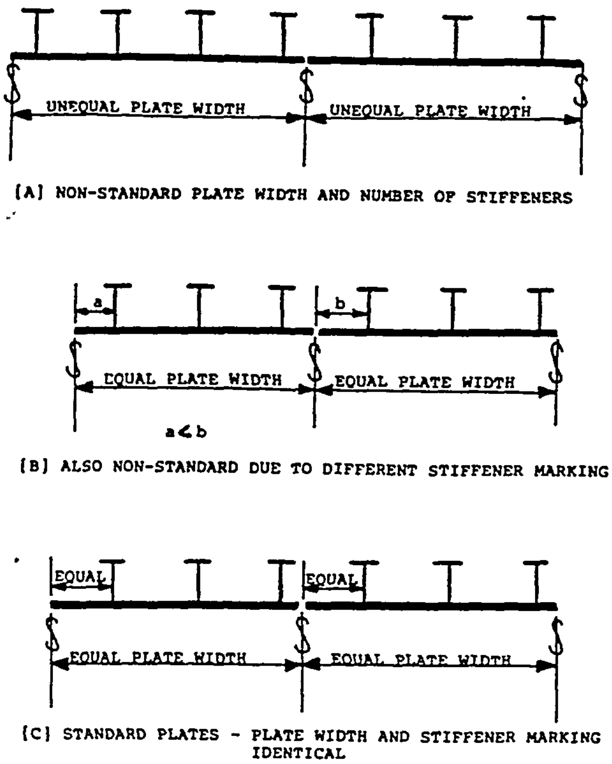


Fig. 13 Standard and Non-standard Plates

One is to consider stiffener and web spacing to suit the maximum width and length of plates to be used. The other is to select plate width and length to suit the desired stiffener and web spacing. For example, if a shipyard desires to use a maximum plate size of 40 feet by 10 feet, the spacing of the stiffeners will be given by 10/n, and of the webs by 40/n, where both n and n must be whole numbers. If, on, the other hand, the shipyard wishes to use a stiffener spacing of 3 feet and web spacing of 1.2 feet, the 40 by 10 foot plate would not allow standard marking. The correct standarad plate size for the

In length and 6, 9 or 12 feet ir, width.. This example shows that when. developing structural design, all the factors that can influence productivity, and thus cost must be included. It is pointless to spend time and more:; to standardize design and facilitieS and tO loose must of the benefit by not understand the impact 0f incorrect plate standardize~ ion. Correctly apclied, the.":sourceof dfferentshell plates in the parallel body 0f a tanker or bulk carrier, can, be as few as five. When this appreac is applied to decks, bulkneads and tank tops, its impact can be a significant reduction In engineering, lofting and production man hours. It also makes the use of special toolling cost effective and practical, as the exten.t of tooling will be small.

Another shell detail that involves extra work content is insert plates. This is because of' the additional welding and chamfering of the *insert* plate. This can be eliminated by making the insert plate the full strake width, thus elimin-~ sting much of the additional welding. The chamfering can be eliminated by increasing the thickness of the plating surrounding the insert plate to that necessary to gradually build up to the required Insert plating thickness in steps allowed by the classification society rules, without chamfering.

The consideration of the framing method, that is transverse *or* longitudinal, and plate straking direction should be performed together. This is because in general, straking should be in the same direction as the framing. This iS to eliminate the need for rat holes over plate butt welds or for grinding down the weld beads in way of framing crossing the welds. Obviously, this cannot be adhered to in all cases, especially bulkheads where the plating thickness varies with depth and vertical stiffening is generally preferred. The age old practice of keeping the molded side of the plating flush where plating strakes vary in thickness is a problem for panel lines due to requiring the upper surface of the panel to be flat for stiffener installation. In such cases, it may be better to locate the stiffeners on the uneven side running parallel to the plate straking. For horizontally straked plates this would require horizontal stiffeners with varying scantlings for the stiffeners, and a system of web frames, which is probably not the minimum work content approach. From a productivty point of view, it is probably better to use vertical plate straking and vertical stiffeners, ever though there will be an increase in Weight~ due to the constant plating thickness.

Many shell assemblies and/or modules require plate or pin jigs to be able to construct them. This is an additional work content and by design it can be eliminated. To do this it is necessary to either arrange flat structure, such as decks, flats and bulkheads, into the shell module so that they can be used as the assembly reference planes on which to set the internal structure and then attach the shell plates. Or else the internal web frames must be deliberately designed with their inner surfaces in a common plane for each module, in the same way that the upper surface and bevel angle of roll sets are used. These concepts are shown in Figure 14.

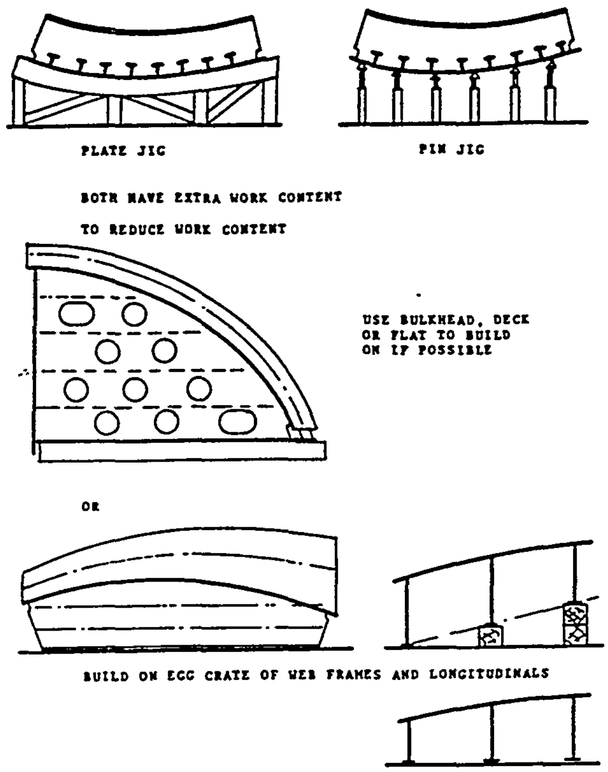


Fig. 14 Curved Module Design for Production

cut-outs

The design of cut-outs for frames, longitudinal and stiffeners can also adversely influence work content, especially in naval work, where most of them at the shell must be chocked or collared. It is possible to eliminate cut-outs by *slotting* the floor, web or bulkhead; cutting away the flange of the frame, longitudinal or stiffener; and inserting a bracket to effectively maintain the sectional area of the frame,etc.

Corner cut-outs, snipes, drainage *and* air holes' must take into account the construction methods and equipment that the shipyard intends to use. For example, if automatic or even gravity feed welders will be used, a detail allowing continuous fillet welding will be best, whereas for manual welding a complete edge cut detail may be better, especially if weld oil/water stops are combined in the detail.

The practice of making air holes smaller than drain holes in floors, girders, etc., is uneccecessary and the:: should be made the same size.

Brackets

brackets were very simple. Even where shape was Involved, they were fitted at the ship frame by frame. Figure **15** shows the"evolution of some frame and beam brackets. Type (A) is a pre-computer aided lofting and N/C burning bracket. It was often sheared or burned from plate drop off or scrap and two standard sizes generally covered the complete ship. Standard II was used for shaped brackets and the excess material was simply cut off to suit each connection when Joining frame to beam. Type (B) shows a bracket which is practical only through the use of computer aided lofting and optical or N/C burning. As type (B) can be accurately cut, It can be used with advantage to align frame to beam and shell to deck. Type (C) is a bracket which utilizes the same concept as type (B) but attempts to eliminate the complex cutting of the ends of beams, frames, stiffeners, etc., required by type (B). Its advantage is that as it is cut by N/C machine, all shaping can be easily accomplished and then the end cut on the frame, etc., becomes a simple straight cut. Its disadvantage is that as it is still used for alignment, it usually requires a larger bracket, thus encroaching on internal space. Another way to reduce the work content of brackets is *to use* thicker material and eliminate flanging or welding on a face plate. This is allowed by classification rules.

Web Frames

Ships such as tankers and bulk carriers, and also some large naval ships, incorporate many web frames in their structural design. The usual design *approach utilizes ring* web frames with their many face plates and web stiffeners. Figure 16 shows typical ring web frames and an alternative approach utilizing non-tight plate bulkheads in place of the ring web frames. The non-tight bulkhead web frame can be constructed for less *man hours* than the usual ring web frame as it eliminates many differing parts Including thick face plates which are often rolled to shape. It can also be constructed on a panel line with automatic and semi-automatic assembly equipment. However, in the case of coated spaces, the cost increase for the coating Of the additional surface area, must be taken into account. Where ring web frames must be used they should be simple in design without any curved inner contours or shaped face plates. Also the face plates should be located on one side of the web and *not* centered or even offset as a "tee".

Access

The location of access holes through the structure is important from the productivity point of view and must be considered for all positions of the assembly or module during construction and not only for the final ship attitude, as

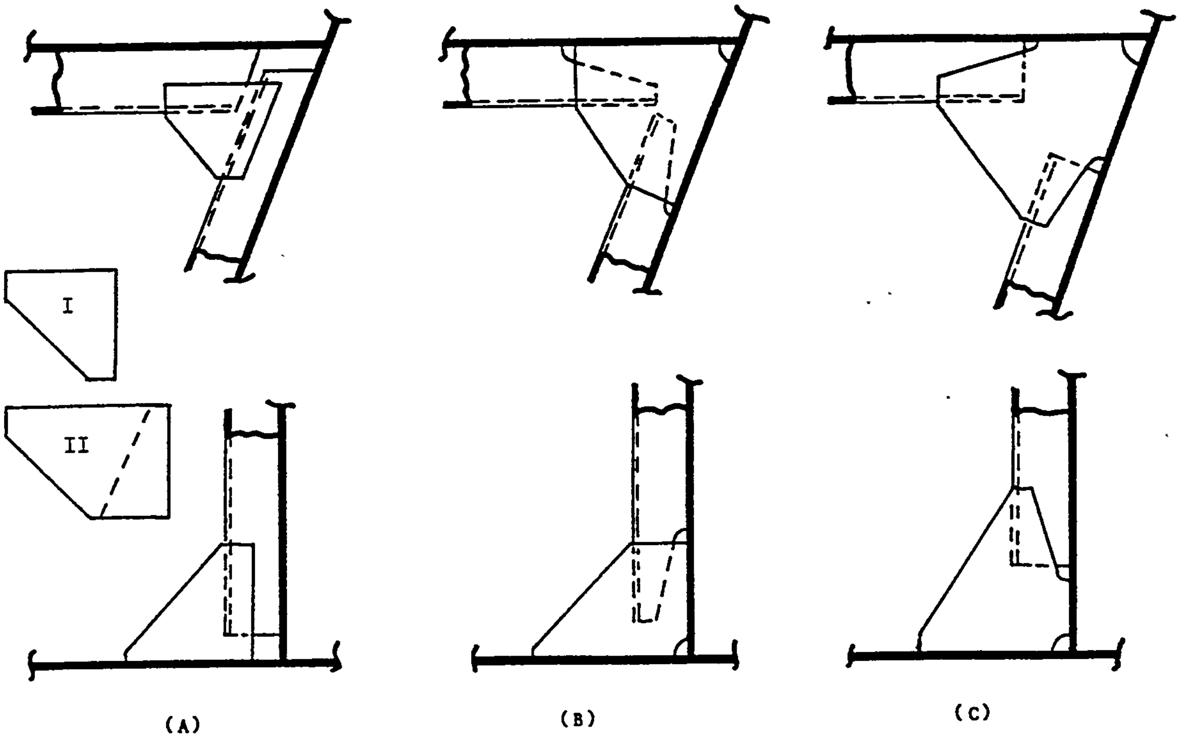


Fig. 15 Bracket Evolution

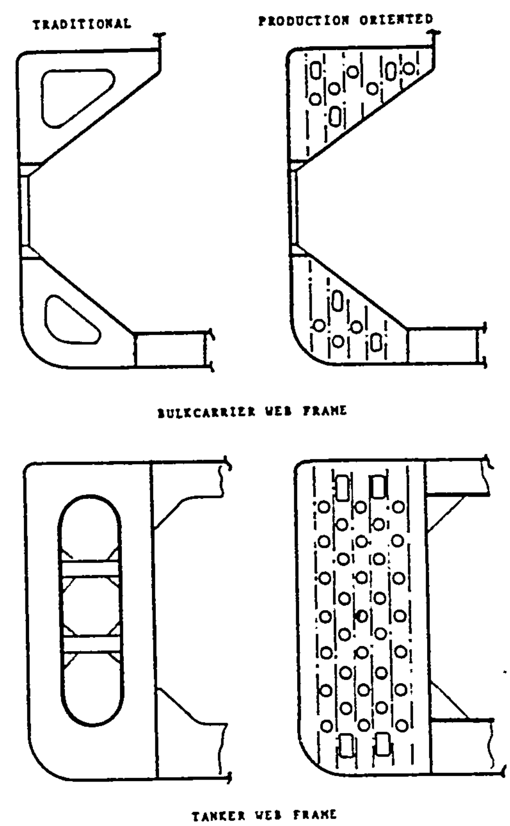


Fig. 16 Web Frame Alternatives

illustrated in Figure 17. It is a noticeable practice of many designers to center access holes in floors, girders, etc. , making them difficult to use, and often requiring steps to be installed.

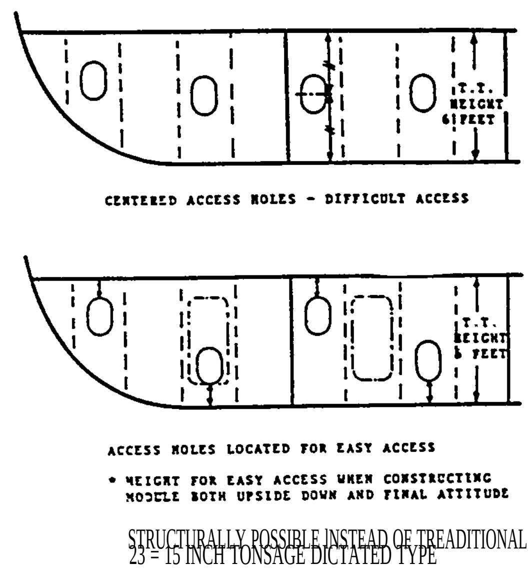


Fig. 17 Location of Access Holes

During the construction and for maintaining the ship in Service, Staging is required in many spaces. This can be eliminated by integrating the requirements into the design as permanent feat ures. For example, for staging, 3 inch diameter holes can be cut in floors,

girders, web frames, deck transverses, etc., through which 23 inch diameter staging pipes can be placed and staging planks laid across the pipes. This concept was shown In reference (9) which also showed the cutting of hand and toe holes In the structure to assist access throughout the ship. These staging and access holes can be efficiently cut by the automatic burning machine when cutting the plate. Permanent "buiit-in" construction and access "galleries" are also a possible way to improve productivity through improved and safer access.

Penetrations

One area of significant work content faced by shipbuilders of naval and other sophisticated ships, is the cutting of penetration holes for pipe, HVAC and electrical systems. This must obviously be done for systems where they pass through bulkheads, decks and external boundaries, but it is usual practice to see it also for deck transverses, girders and web frames. The need to penetrate the lattter items should either be eliminated or they should be made easier to penetrate. It can be eliminated by the design of minimum depth members and the running of all systems inside of the members or if the members cannot be made smaller, by increasing the tween deck height or width of the space to allow the systems to be run inside of the ' usual sized members. Members can be designed to be easily penetrated by systems. That is, the depth of the member can be increased and the web material cut away in a standard pattern, to allow the systems to pass through. Figure 18 illustrates this concept.

Scantling Standardization/Number Reduction

In a recent Contract Design for a small 224 foot naval service ship, the design agent utilized 12 different thicknesses 0f plate and 51 different shapes. Although one or the worst examples ever seen, it is, unfortunately, quite common for designs to be prepared without any regard to keeping size differences to a minimum. An example of what can be done in this area Is the case of a ship-*owner's* Contract Design which had 30 different shapes. The shipyard reduced these to 9 during detail design with less than a 1 percent increase in. steel weight. However, the man hour savings resulting from the easier receiving, stering, handling, processing and Installing was 6 percent of the steel construction on budget.

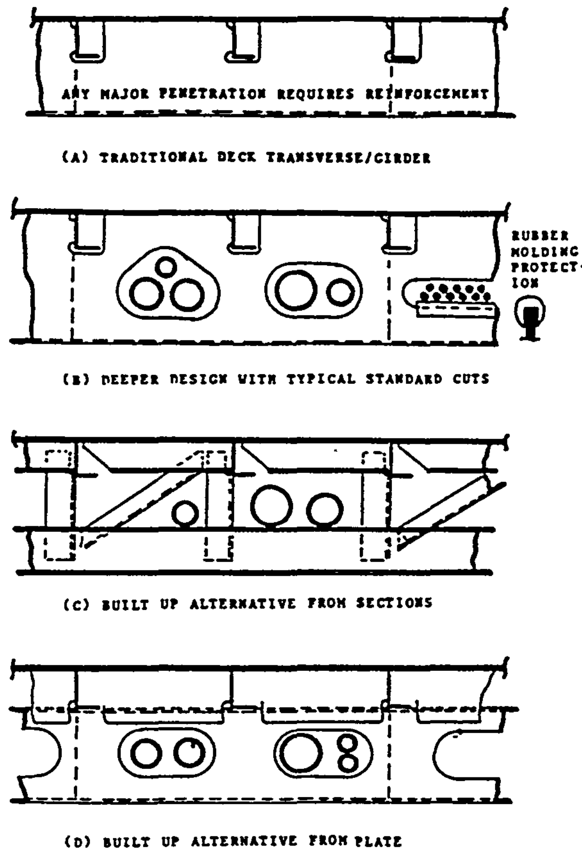


Fig. 18 Penetration Alternatives for Transverses and Girders

of the Iongitudinals is a productivity improving alternative. Obviously, with computer aided lofting and N/C burning, the bilge brackets are easily produced. This approach also provides simpler and better control of the shape of the bilge shell plates.

Obviously, before utilizing any of the structural details proposed, a complete producibility/cost benefit analysis should be performed by each shipyard to ensure that the selected detail is the best for their particular facility, equipment and methods.

STRUCTURAL FITTINGS

It is usual to group certain Items which are either integrated intc the structure, such as stem and stern frames.es, or connected to it, such as bitts, checks, steel hatch covers, manholes, ladders and structural doors, into a category which is commonly known as Structural Fittings. Foundations are sometimes included in this category. Many 0f the items in this group were castings in the past and have beer. replaced by welders, such as bitts, stems and stern. frames.

There is considerable Qpportunity to apply design for production techniques

to structural fittings. For example, when welded stern frames were first designed to replace castings, they were still designed as an Independent Item from the rest of the stern structure and this is still being done by many shipyards. With modular construction there is no logic for this and the stern frame should be integrated into the stern module. The work content would be significantly reduced by this as the stern frame is effectively eliminated as a separate work item. The replacement of the stem casting by a weldment was already discussed, but it obviously requires the cooperation of the designer of the lines to be able to do so.

The traditional design of rudders results in high work content rudders. This can be reduced by simplifying the design through the following approaches:

- Constant section throughout the depth
- Vertical leading and trailing edges
- Spade rudder instead of rudder supported by sole piece or horn
- Horizontal bolting coupling instead of tapered stock and nut.

Foundations for marine equipment are traditionally pedestal type made out of plate. They usually support only one piece of equipment. Even before advanced outfitting was developed, it was an obvious productivity advantage to integrate the foundations for multiple associated equipment. The unitlzatior, as it is called, of steering gears, hydraulic power plants, inert gas systems and purifier installations have been commonplace for some time. The use of standard foundations is obviously worthwhile due to reducing design, engineering and lofting effort and production fabrication and installation man hours due to multiple runs and work familiarization. Foundation design for production depends on shipyard equipment and worker capability, but, in general, the following approaches have provided low work content design:

- o Minimize number of parts
- Minimize number of unique parts
- Foundation designer and equipment arranger must work together. Sometimes moving the equipment a few inches can significantly simplify the foundation design and construstion with no adverse impact on the arrangement design.
- Do not mix plate and shapes. that is make the foundation completely out of either all plate or all shapes.
- Standardize on a few structural shapes, such as angle, channel or square tube.
- o Pun supports vertical Do not slope supports.
- Provoide any required “back up structure” on the same side as the foundation. That is integrate it with the foundation
- Eliminate fitting joints, maximize lapping joints
- Use sheet metal independent drip pans in lieu of built-in
- Group a number of’ small items onto a common foundation
- Securing bolts must be easily accessable. Otherwise, provide studs

For the remaining structural fittings, the use of standards is an essential design for production approach. It is illogical to redesign and/or redraw items such as hatch covers, railings, structural doors, ladders, flag and ensign staffs, etc. for **each new** design.

One item that is surprising in its lack of standardization in many shipyards is manholes and their covers. For some reason the cover and gasketing for the coaming, raised and flush types are not made the same. There is no reason why this should be so. It is the different parts of each type that should be designed to suit the standard *cover* and gasket.

Obviously, not all of the possible structural fittings have been covered, but the intent should be clear from those that were.

HULL OUTFIT

Hull outfit covers joiner work, insulation, furniture, habitability equipment, deck covering and painting. In some shipyards, it also covers deck machinery, hull piping and HVAC. The two latter items will be discussed separately in the following sections *on* PIPING and HVAC, respectively.

The major item of recent development in hull outfit that is in keeping with design for production, is modular accommodation units. The advantages of modular accommodation units are, not surprisingly, similar to those for advanced outfitting units, namely:

- Relocation of work from ship to shop, resulting in easier access, efficient material handling, cleaner and safer environment
- Possibility of assembly line techniques for multiple units
- Elimination of transforming many small items to ship
- Simpler material control
- Reduction in material scrap
- Shorter installation time onboard the ship

Again, stardardization is an essential design, for production approach, not only for individual items outfor units such as modular toilets, modular furniture, ccmplete cabins, gallers and storerooms.

A number of design for production

ideas for hull outfit are:

- Incorporate foundations for deck machinery into the equipment design and weld direct to the structure
- Use above deck slide or "A frame" anchor davit instead of hawse pipes
- Use modular accommodation units. If not complete cabin units at least modular toilets, modular furniture and common outfitted joiner bulkheads
- Keep furniture off the deck. support by joiner bulkheads, as this will eliminate sub-bases and their fitting to the deck
- Use modular galley equipment/walls
- Use carpet over bare steel in cabins
- Use trowelled in place deck covering in passageways
- Use non-grinding terrazzo in galley and toilets

Another idea that results in significant work content reduction, is to apply hull insulation to joiner linings and ceiling instead of the inside surfaces of hu11 and deckhouse structure. This eliminates work effort for fitting insulation between and around frames and beams as well as cutting flaps for welded supports for vent ducts, piping and wireways. Many of the currently available modular accommodation systems use this approach, but It can be and was used by a shipyard in Sunderland, England in **1964** for traditional joiner lining and ceiling installations. As previously mentioned in discussing arrangements, service spaces should be provided adjacent to each toilet, laundry and other service locker, which can be accessed by easy removal of joiner lining/bulkhead panels.

MACHINERY

Very few shipyards today design and manufacture the propulsion and auxiliary machinery which will be installed in the ships that they build. They will probably purchase the machinery from other manufacturers who specialize in the manufacture of the different machinery items. Therefore, the machinery design group is usually responsible for designing an integrated power plant from many "stock" or "standard" items of equipment available from many different suppliers. They may also be responsible for the design of the machinery space ventilation, gratings/Floor plates and ladders.

The design of the machinery installation can significantly assist the ultimate goal of improved productivity by standardization. For example, found,ations for propulsion and auxiliary machinery could be standardized for the equipment and different ship structural arrangements designed to suit the standard foundations. Some years 25c, Let Merske Veritas atempted to standardize the arrangement of machinery spaces for different ship types. The idea was that all equipment associated with a given function or system should be grouped together and located in the same area for similar ship types. the Idea is *sti:: a* good one as it allows the familiarization of both shipbuilders and grew of similar machinery plants for different ships. By utilizing such an approate. and assigning vertical and horizontal system routing corridors for the different systems, such as piping, ventilation and electrical wireways, the task of other engineering groups and production can be significantly simplified and reduced. Again, considerable engineering and production man hours can be saved by standardizing the system routing corridors.

Assembly and module breaks must be carefully developed between the mackinery and hull groups to ensure that no major equipment or their foundations extend over the breaks as this will prevent installation of the equipment into the modules before erection and joining.

Machinery Arrangement

Even with the recent trend to un.-attended engine rooms and complete automation, ship machinery plants will still have maintenance and overhaul work performed on it regularly throughout Its life. While much thought has been applied by machinery manufacturers during design, for easy maintenance of their equipment, it often seems that little is given by the ship designer in the arranging of the machinery. The recent introduction and application of Human Factor-Engineering if applied correctly should change this. During Contract Design, efficient transport routes for spare parts and tools must be developed along with good working space for required equipment withdrawal and maintenance, lifting capability, stores and spares locations, etc. Floor plate level and the level of the machinery space flat/s should be determined to be the most efficient for maintenance work, without compromising normal operational requirements.

The arrangement of machinery, equipment and systems should be designed for easy cleaning. With reduced engine room crews, less time is available for this function, which is normally very difficult due to the dirt which aceptulates when fuel, oil and water mix. Proper design of drip trays under equipment and of draining and collection. system for same can assist in accomplising this goal.

The lifting and transportation. of equipment and spare parts should be considered for all machinery and large equipment, not just the propulsion engine and gear. The manual chain hoist is still needed in most machinery space

of current ships. With small engine room crews this is no longer acceptable.

The location of spare parts should be an integrated part of the machinery arrangement design process and not simply left to whatever space can be found when the ship is nearing completion. When designing the supporting distribution systems, a balance must be maintained between minimum equipment and multiple uses and the design which would be best for operations and maintainability . Design for production should not be applied to the detriment of design for efficient operation and maintenance.

The machinery arrangement development obviously must take into account whether or not advanced outfitting is to be utilized. The equipment association list, the network and the final diagrammatic are the basis for the design of an advanced outfitting machinery unit. The arrangement of the equipment and the overall dimensions of the unit will be affected by the space available in the machinery space and the other equipment/ units therein. It is therefore, normal for the design of the unit and the arranging of the machinery space to be performed concurrently. Units should be arranged with the following points in mind:

o Identical units for identical major equipment should be located identically (True Modularity)
0 Units should be located with both the major equipment and the system storage tanks in mind so as to provide both the best operational and least cost arrangement
0 Completely forget the traditional concept of mounting equipment on bulkheads, unless all the unit equipment will be installed as a unit onto the bulkhead. The design of a unit must be developed from the concept of support from only one plane. Occasional braces can be allowed for high small plan **area** units
G Units should be arranged so that all piping runs are as snort as possible and only in the transverse and longitudinal directions. Diagonal runs should be avoided unless absolutely necessary to suit unit design
c c In conjunction with the arrarging of units, distribution system corridors should be established. There possible major routing corridors should be integrated with floor plates, gratings, walkways and their supports
c Personnel access system (floor Flates, gratings, etc.~ should only ce that required to provide access to equipment for.necessary. service funtionstlcns such as normal and emergency operation. and maintenance
0 Maintenance lifting or pulling arrangements should be frilly considered when designing the ‘arrangement and incorporated into the unit where practical
0 Handrails should be arranged for safe access and protection, both during construction and after installation of the unit in the ship
0 Combine as many system as possible into a unit with good design and producibility in mind. For example, if large vent ducts **are in the vicinity**, attempt to combine them with walkways
0 Valves should be located so as to come up at the side of the floor plates and grating, as show in Figure **19,** and not below or through the middle of the floor plates

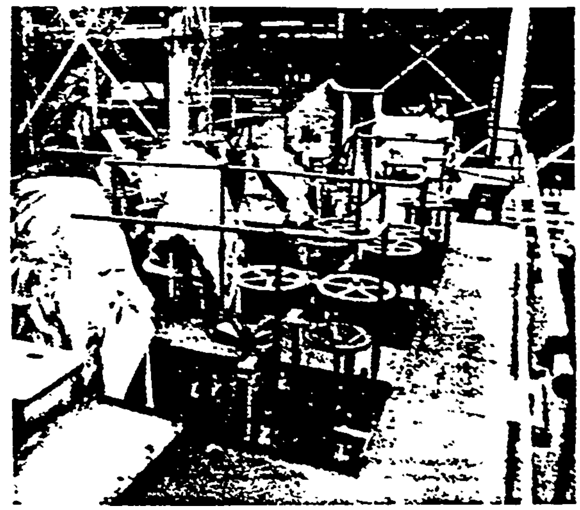


Fig. **19** Valve Location for Production and Operation

Space Allocation

The selection of the locations for all equipment, appurtenances and systems should be performed in a logical and formal way. This is true for all parts of a ship but is essential for machinery spaces. An aid to this process is the analysis of existing ships to determine space requirements for the various machinery, equipment, distribution ccrridcrs, etc. Major independent machinery: and standard auxiliary machinery units can be represented by the circumseribing block. To this can be added the surrounding space necessary for access, operation and maintenance. Such space should be designated as to whether it is inviolate. Then these can be used to develop a forctional machinery space layout. Such a layout is conceptually shown in. Figure 20. It is important to Logically design the distribution corridors **and not just** provide space For them. When the corr - idors for different systems *such. as vent, pipe* and wireways must cross each other, the concept of how this will be zone must be developed.

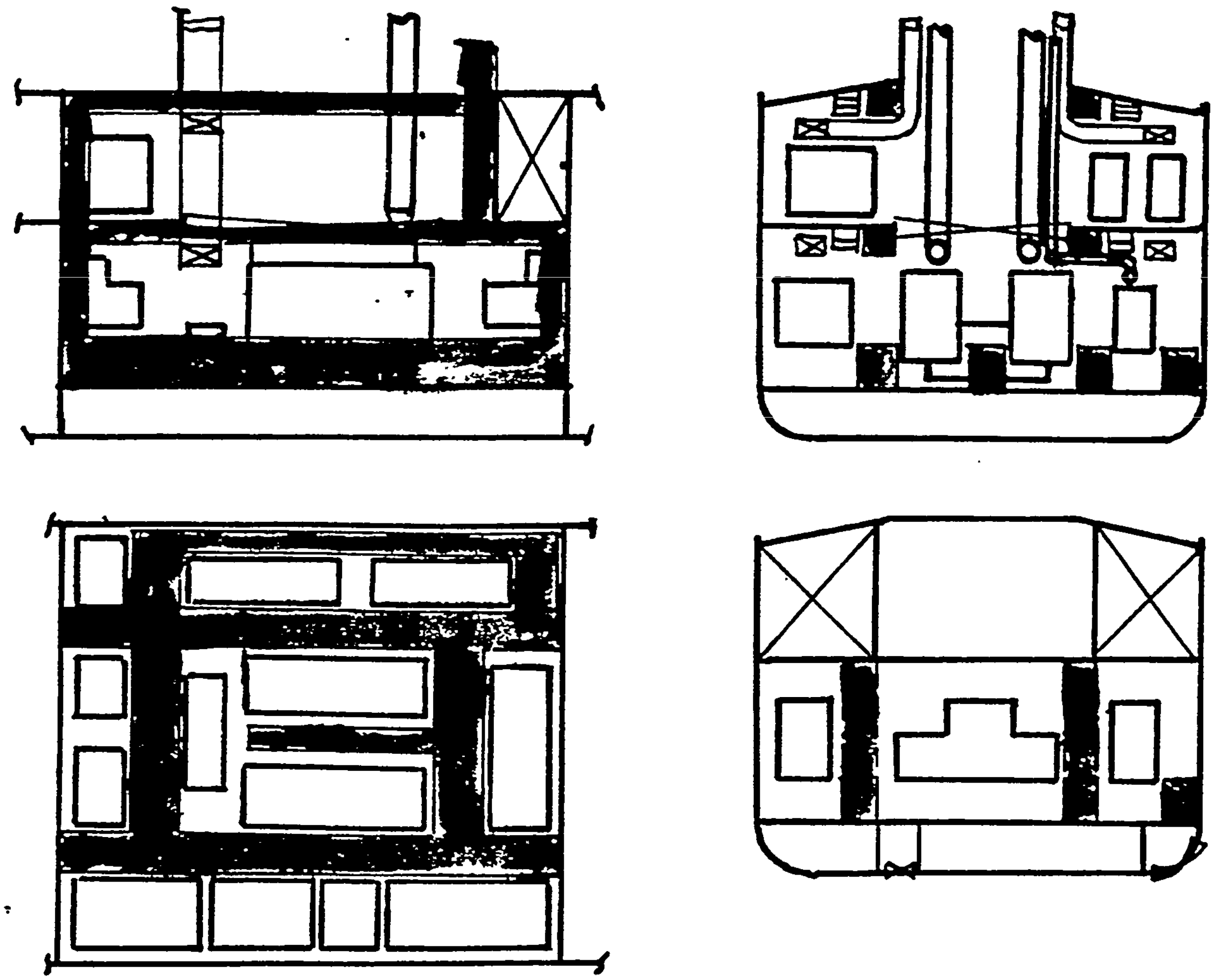


FIG. 20 Space Allocation

Equipment Grouping

Even before the concept of advanced outfitting it was good design practise to prepare an equipment association list for any major piece of equipment to be arranged and installed in a ship. This association list was used for a number 0f purposes,. such as checking vendors supplied unattached equipment. However, for the purpose in mind, it was and should be used to develop location in. the system of all the items and the connections between them. Equipment which requires a foundation can also be noted. The additiona of avlves, gages, switches, etc. , is accomplished when preparing the diagrammatic. The equipment association list was then used to develop a ccnnection network, which became the basis for the system diagrammatic. For **ad**vanced outfitting "On Unit" construction, it is necessary to use the equipment association list and the connection netword to sleet the best *grouping of* the equipment on the unit. A tyypical equipment association list is shown in -: and Figure 21 is the resulting network. figure 22 shows a typical design diagrammatic prepared without any consideration of equipment association grouping. It is easy to see the illogical location of the equipment. Figure 23 shows the same diagrammatic developed from an equipment association network.

TABLE IV

EQUIPMENT ASSOCIATION LIST

SYSTEM/S:	Propulsion Diesel Engine L. O. Service
MAJOR . EQUIPMENT:	Propulsion Diesel Engine
ASSOCIATED EQUIPMENT:	L.O. Standby/. preluse Pump L. O. Filter L. O. Cooler L. O. Duplex Strainer Rocker L. O. System Tank Rorcker L. O. Standby Pump

Floor Plates

One area where many shipyards spend an inordinate amount of effort is in the installation of machiner:: space floor plates. This is usually because they are designed independently of other

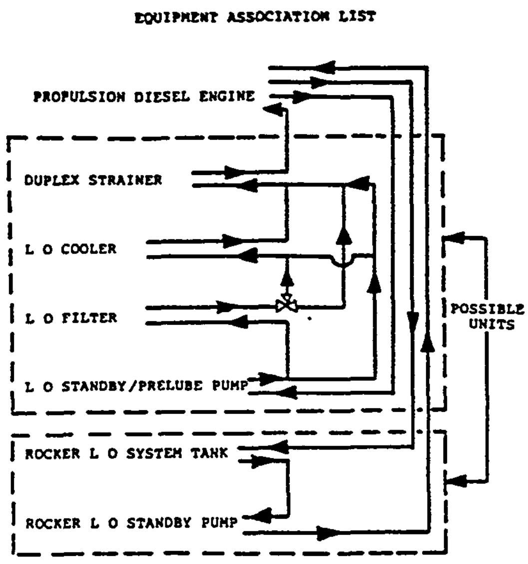


Fig. 21 Equipment Connection Network

systems and always seem to have many interferences. To avoid this they end up being custom fitted onboard the ship. The application of advanced outfitting "On Unit" approach will eliminate much of this problem as can proper design sequence when advanced outfitting is not used. Notwithstanding the many bad experiences with floor plates, it is possible to successfully design and install a standard floor plate system. It is beneficial to keep the area alongside the propulsion machinery clear of systems so as to eliminate the possibility of foundation/system interferences. This also provides a maintenance work area and by incorporating hinged floor plates, maintenance and access to the machinery is improved. The practice of designing machinery space handrail stanchions of pipe as well as the rails should be discouraged and the simpler "hull type" flat bar stanchions used instead.

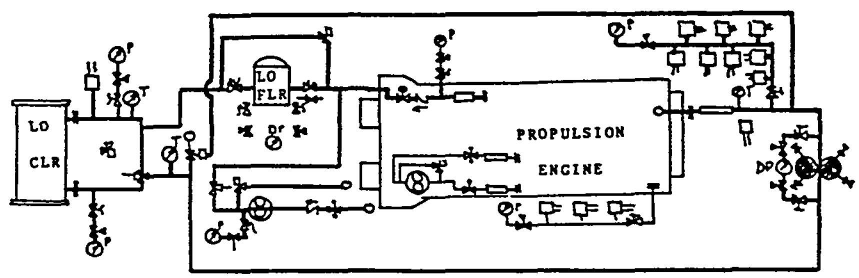


Fig. 22 Illogical System Diagrammatic

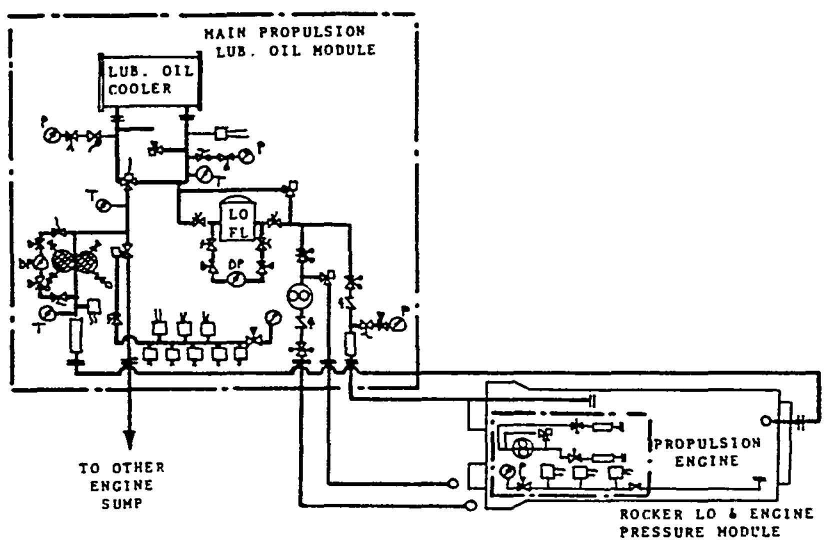


Fig. 23 Logical System Diagrammatic

PIPING

The design of piping systems for a Contract design usually only consist of unsized diagrammatic for propulsion and operational essential systems. Like all other systems, standardization will assist in accomplishing design for production. not only standard components but standard complete systems, such as shown in Figure 24, and standard routing corridors. Again, whether or not advanced outfitting will be utilized, the steps outlined in the section *on* Machinery Arrangement should be followed and expanded, namely:

- o Prepare equipment association lists
- o Prepare equipment connection networks
- o Prepare system diagrammatic
- o Prepare routing diagrammatic

As the Contract Specifications for piping systems usually define in detail aspects which affect productivity, the designer should be fully aware of this and take it into consideration when preparing the Contract Specifications and not simply copy from a previous specification.

Individual design for production concepts *for* piping are worth development as there is significant opportunity for productivity improvement. The combini ; of a number of pipes into bundles *or* units has already been mentioned. ~' - use of pipe intiustry purchased hange should be fully evaluated, compared to individual shipyard design and fabricat ion. Special hangers combined with unique support systems such as those offered by UNISTRUT, are worth considering. Another concept that is widely and emotionally discussed by many is the use of flanges as installation joints in, stead of welded joints. Flanges are used extensively in foreign shipbuilding but have been resisted in the U. S. The use of DRESSER pipe couplings and VAN-STONE flanges can reduce the installation man hours. One point of importance is that, flanged pipes can be locate closer together than welded pipe due to the heed for space to get in to weld the the pipe joints. For bulkhead penetrations a flange connection at both" sides of the bulkhead and installation during structural assembly can save many piping installation man hours. Multiple penetration plates are also work content reducers. The use of PVC and fiberglass pipe can reduce the fabrication and inst allation man hours corr ared to tradition-

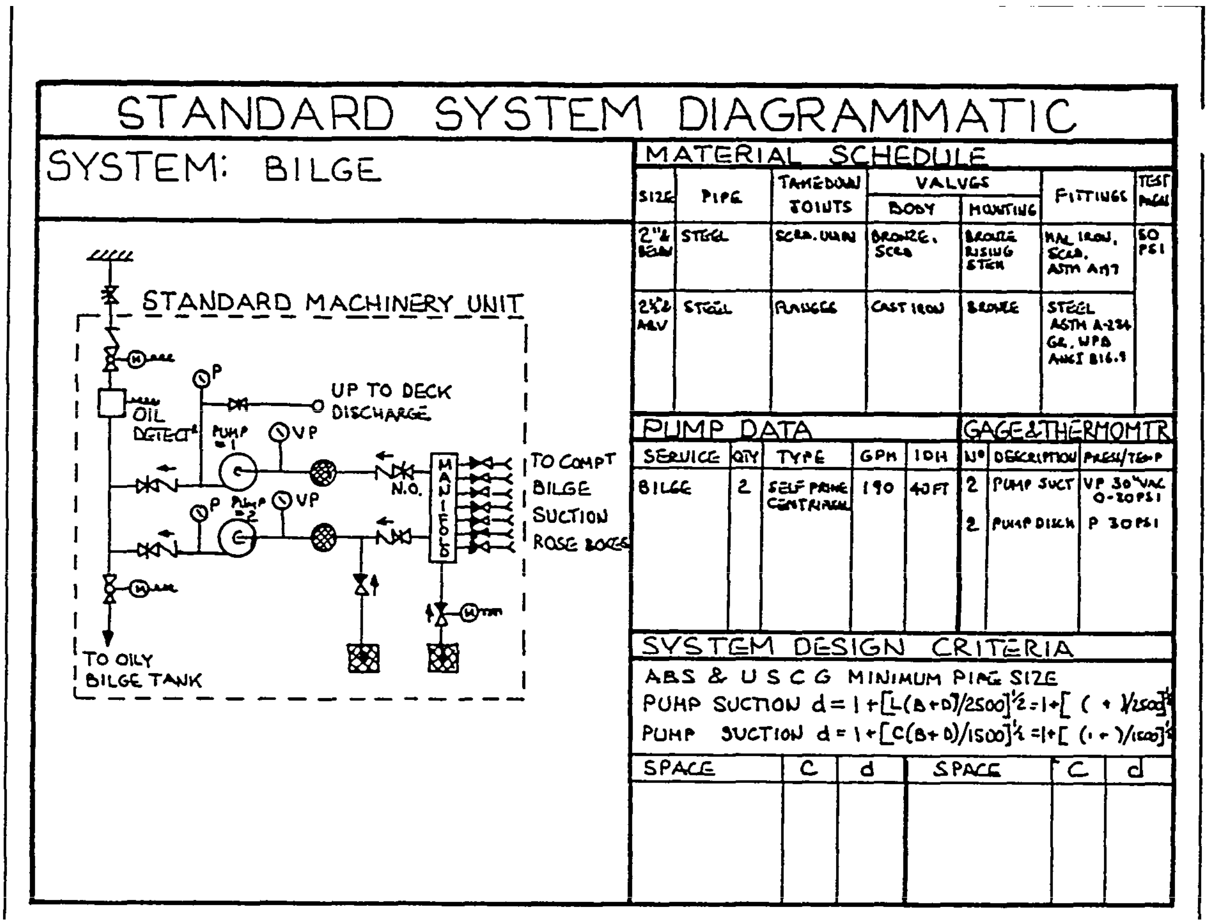


Fig. 24- Standard System diagrammatic

al metal pipe. This results from the easier handling of the lighter pipe and the simpler joining methods. There are certain ship systems for which PVC and fiberglass pipe cannot be used, but where they can be, they should be fully considered.

A thorough investigation of the fabrication and installation benefits should be undertaken by a shipyard before adopting any of the above ideas. However, the Contract Specifications must be written to allow them and thus eliminate the extra effort required to develop a change order once the Contract is awarded.

HVAC

In traditional design and construction of ships, systems such as piping, HVAC and electrical are always "fighting" each other for space. To overcome this problem some designers allocate space priorities to different systems such as HVAC first, large piping next and electrical wireways last. Unfortunately, from experience it is known that this approach does not work well. This traditional conflict does not end with design and engineering. It continues out in the shops and on the ship during construction. Added to this shipboard conflict caused by design, is the "field run pipe" and "who gets there first" problems. However, these problems can be changed into planned integration of systems by applying the approach described herein.

An essential step to ensure production friendly design of HVAC systems is to plan the distribution corridors early in the design development at the same time as the corridors for the other systems. Again, the use of standards for HVAC components and diagrammatic is an effective design for production approach. Obviousiy, the standards should be minimum work content designs. By correctly planning the design of HVAC systems during Basic Design the need for high work content penetrations, duct jogging and section changes can be eliminated. By considering louvres and plenum chambers as Integral parts of the structure instead of HVAC fittings considerable design and construction man hours can be saved . The use of high pressure ventilation systems will reduce the size of the ductlng and can result in worthwhile installatlon man hour savings. However, the cost of any special noise attenuation treatment could cancel the savings out . The use of individual room convectcr heater/cooler and even hotel type through the wall units should be examin.-ed as a potential productivity:: improver without any operational dissadvantages. Again, the above ideas must De considered during the preparation of the Contract Specifications to ensure that they can be utilized if found of' benefit to a shipyard.

ELECTRICAL

As for the other traditional disciplines, the first design for production " requirement for electrical systems is that they be considered allong with and integrated with the other systems. This integration of all systems is essential if an efficient and easily constructed ship is to be designed. Routing corridors for wireways should be assigned during Basic Design and used for cable routing as the design is developed.

Marine electrical design and engineering is the ship discipline that has had the least effort expended to improve it. The design for production potential is therefore large and it should be targeted for significant development. The impact of advanced outfitting and zone construction is substantial on traditional marine electrical design but can be used to guide the required electrical design for production development. Aspects such as combined control panels for units, On Block and zone electrical installation, erection of completed deckhouses, etc., must be considered and, again allowed for in the design approach and the Contract Specifications.

INTEGRATION OF SYSTEMS

Everyone knows that the most cost and operationally efficient ship is one in which all its components are well integrated. Many also know that the intgration of the many systems also offers work content reductions. Therefore, the deliberate efforts to Integrate the ship systems during design is an essential part of design for ship production. The approach is not new. It is just that the traditional engineering specialization/organization divides responsibility for individual systems in the same part of a ship to many *groups*. Also the preoccupation with independent system design and current approach to working schedules apparently prevent many designers from attempting integrated design. The integration of systems for advanced outfitting units is simply a micro application of the approach compared to the macro application for the complete machinery space or the entire ship. The specialization of skills in both engineering and production relies on the ability of managers to ensure that the design and construction of individual systems result in an integrated final product. This iS accomplished is some industries by the use of Systems Engineering and specialized Systems Engineers. The Systems Engineers can be found in both staff and line management positicns and their interface with traditional designers can be either before or after the design of the individual systems is completed. What-

ever the approach, it is obvious that there is a basic design need to ensure that all parts of a product are efficiently integrated and that the many compromises that are necessary during design are the best. In the past this function in the shipbuilding industry was performed by the managers and supervisors of design and engineering. In many cases it has work and still works well. It is obviously impacted by the engineering organization.and this should be arranged so that the work responsibilities naturally assist the system integ- . ration function by having groups responsible for all the engineering in specific parts (zones) of the ship.

It is still possible today to see machinery spaces where individual pipe runs have obviously been designed and installed independently of all other pipe runs. Further, no attempt will have been made to Integrate the pipe hangers with each system being independently "hangered" to the ship's primary structure. The foundations for the equipment will be individual and floor plate and vent duct supports will also be independent. When surrounded by this inefficient application of material and production effort, it is easy to see the additional cost and weight and why it takes so long to build.

Advanced outfitting necessitates integration of systems to obtain full benefits. An Innovative but practical attitude is required to successfully integrate the systems and a major tool to assist this is a Distributive System Routing Composite Drawing incorporating the assigned system corridors.

CLOSURE

The objective of this paper is not to promote any of the design details to be used by a shipyard without a thorough study to determine what is the best for that shipyard. If the paper stimulates other designers to develop better design for production details, the author will feel that it has accomplished itS purpose.

During the lectures On Design for Production and when discussing the subject with many associates, the response is often that the ideas are just good common sense. While this may be true in part, that common sense isnot being used enough. If it was there would be no need for this and similar presentations. yore **imp0rtantly, our** our shipbuilding productivty rates woould be better. Therefore, it is hoped that design for ship Production will become an every **day part c:-** Basic Design., especially during Contract Design arid Specification pre- **paration,** for future snip designs in this country. In this way ship designers will play an important part in improving the productivity of U. S, shipbuilding.

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DESIGN FOR PRODUCTION IN DETAILED DESIGN

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Engineering for ship Production

Thomas Lamb'

Engineering for Ship Production is the use of production-oriented techniques to transmit and communicate design and engineering data to various users in a shipyard. The changeover from a traditional craft-organized shipyard to one of advanced technology has obviously had a tremendous effect on all shipyard departments. It should have had its second greatest impact on the engineering department. However, *many* engineering departments did not rise to this challenge and, therefore, bst what might have been a lead position for directing and controlling change. Production performance depends largely *on the* quality, quantity, and suitability of technical information supplied by engineeering By organizing for integrated engineering and preparing design and engineering for zone construction, engineering can step forward and take its proper place and play an essential role in the renaissance of U.S. shipbuilding. Using examples, this paper describes how this can be done.

Introduction

ENGINEERING FOR SHIP PRODUCTION is the use of production-oriented techniques to transmit and communicate design and engineering data to various users in a shipyard. There has been increasing interest in this matter during the past few years as witnessed by discussions on the format and content of engineering drawings. Instead of focusing on engineering drawings, discussion should center on what technical information is required to procure and construct the ship, and what is the best way to prepare and transmit this information.

The format of engineering information, including the content of drawings, has developed *over* many years. Changes and improvements have occurred very slowly, and in some shipyards and design offices, not at all. Traditionally, shipyards were craft-organized and only required the minimum number of drawings for which accuracy was not essential. The loft prepared the templates and made everyday decisions on structural details. The pipefitters worked from diagrammatic and developed their own pipe templates from the ship being built. This system was also true for the other shipyard crafts.

The changeover from a traditional craft-organized shipyard to one of advanced technology has obviously had a tremendous effect on all shipyard departments. It should have had its second greatest impact on the engineering department. However, many engineering departments did not rise to this challenge and, therefore, lost what might have been a lead position for directing and controlling change. Engineering simply ignored the needed changes and left them h be incorporated into the shipbuilding process after their work was completed in the traditional manner. Shipyards responded to this problem by getting the necessary production information from other sources, usually new groups that may have been called industrial or production engineering or perhaps from an existing planning group. Some shipyards even accepted the fact that engineering information was inadequate for production and left it to production workers to perform as best they could. This situation often resulted in the same work being done many times before it was reluctantly accepted by the inspectors. It is not surprising that the attitude found in many shipyards throughout the world is that engineering is a necessary evil and that ships are built despite engineering.

production performance depends largely on the quality, quantity, and suitability of technical information supplied by engineering. By organizing for integrated *engineering* and preparing design and engineering for zone construction, engineering can step forward and take its proper place end play an essential role in the renaissance of U.S. shipbuilding. This paper discusses how this can be done, but first considers what is production-compatible engineering (integrated engineering) by comparing it to traditional engineering.

Traditional engineering

Usually all the visual information used by a shipyard production department today is not prepared solely by the engineering department. Most shipyards still have various preparation phases divided in a way developed and used 30 to 40 years ago. At that time, the following division of labor made sense because of the methods used

1. Engineering
   - design and working drawings
2. Loft
   - fill-size fairing of lines
   - layout of structural parts
   - template construction
3. Pipe fitters
   - pipe templates and sketches
4. Sheet metal workers
   - layouts, developments, and templates
5. Shipwrights
   - full-scale layout *on* ship

However, U.S. shipyards have been improving their production processes for years, and their information needs have changed during that time. Some shipyards utilize structural module construction, preoutfitting, advance outfitting and, more recently, zone construction. To perform these tasks from traditional engineering is not impossible, but it requires additional planning and even design and engineering has to be prepared after traditional engineering is complete. This system obviously involves additional man-hours and does not assist the move to shorter performance time.

In many shipyards, the preparation of structural drawings has really not advanced much from the days of the iron ship. Only within the last two decades have a few U.S. shipyards

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prepared their structural drawings as block or module drawings (showing each erection module of the ship on individual drawings) even though they had actually been constructing ships that way for 20 years. Yet most U.S. shipyards and the design agents that support them still prepare structural drawings as item drawings, such as tank top, shell plating or expansion, decks, bulkheads, frames, etc.

The preparation of hull outfit machinery; piping heating, ventilation, and *air* conditioning (HVAC); and electrical drawings has developed over time with progress in the respective technologies. However, these drawings are also currently prepared on a system basis and to differing levels of detail.

In many shipyard *engineering* departments, the installation of hull outfit systems and equipment is conveniently considered a craft akin to cabinetmaking. With this in mind, engineering gives very little data to the production department in the belief it is better left to the master craftsmen. Other shipyards *get* around the need of having the engineering department involved by subcontracting joiner work to companies specializing in this field. In reality, there is no logical reason to give joiner work any less engineering effort than is given to hull structure or piping, especially since outfit can be just as large a *consumer* of both engineering and production manhours as structure or piping.

The machinery drawings are used by the shipbuilder as a definition of equipment arrangement so that other engineering disciplines can prepare their detail design, such as foundations, piping, floor plates, grating, etc.

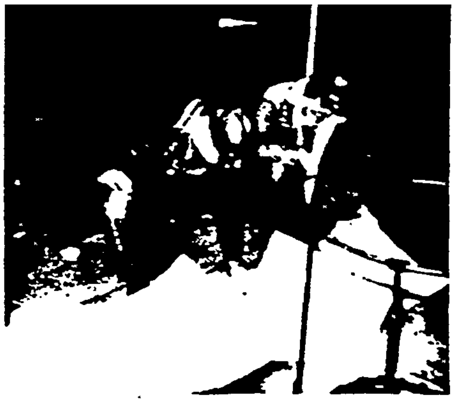
Piping drawings are for individual systems for the complete ship. They may or may not show pipe breaks, hangers, and some production-added information. The same is true for HVAC and electrical, except that electrical drawings are sometimes little more than pictorial concepts with no locating dimensions for equipment.

Usually interference *controI* in traditional engineering is provided by space composites, although engineering models are also used extensively for this purpose. A major problem with this approach is that the electrical crafts go ahead and complete their "hot work" before many of the other detailed systems and composites are completed. The work is performed in the easiest location without checking it or even feeding it back to engineering to locate it in the composites. Apparent production work progress is achieved early in the project, and everyone is happy until the interference problems start and extensive rework *is* required.

Traditional engineering usually includes the bills of material on the drawings or as a sheet of a multisheet drawing. lt also makes use of large drawings, often up to 12 ft (3.6 m) in length. Figure 1 graphically portrays the problem this system creates on the ship compared to the smaller sheets of the proposed Engineering for Ship Production. Since each drawing is for the total ship, but is required each time part of it is used in each module or zone, the drawing must be printed and issued many times, resulting in wasted paper and duplicated effort. Also when reissued because of a revision, planning and production must spend time to deter*mine* how many modules or zones are impacted by the revision.

Traditional engineering is perpetuated by the U.S. Navy '"General Specifications for U.S. Navv Ships" (GEN SPECS), DOD-D-1000, and DOD-STD-1OO. These documents require preparation of drawings, including format, contents, referencing, etc, that are not compatible with the engineering needs for today's best shipbuilding methods.

Traditional engineering drawings contain little production-required information such as module weights, module breaks, system breaks, lifting pad locations, bolting torque,



(a) Problem

(b) Solution: booklet work stationlzone information

Fig. 1 Large drawing handling **problem**

pipe hanger locations, system testing, tolerances, and quality requirements.

Some shipyards attempt to provide some of this information on traditional engineering drawings by having prints of the drawings marked up with production data by the planning/production control groups for incorporation into the original drawings before formal issue. Others provide the required production information on unique additional documents to the traditional engineering drawings.

The practice of referencing instead of including the information on the drawing, other drawings, ship specification, standard specifications, and other data is a serious problem to production. To expect production workers or even their supervisors to have access and knowledge of the references is impractical. Because of this situation, items are often ignored and the work is not "done to spec." Engineering must provide production information *in a clear and* complete manner. This means that engineering must interpret the specifications, use applicable standards, and give all the necessary information. In traditional design where it will still be necessary to list references for data control, this practice must be changed to using references as a way to *record* that the drawing has been prepared in accordance with the references, and not that production should do its work in accordance with the references.

Traditional engineering is not suitable for high productivity, short-build cycle shipbuilding, and therefore, has no place in today's struggle to maintain some semblance of competitive shipbuilding.

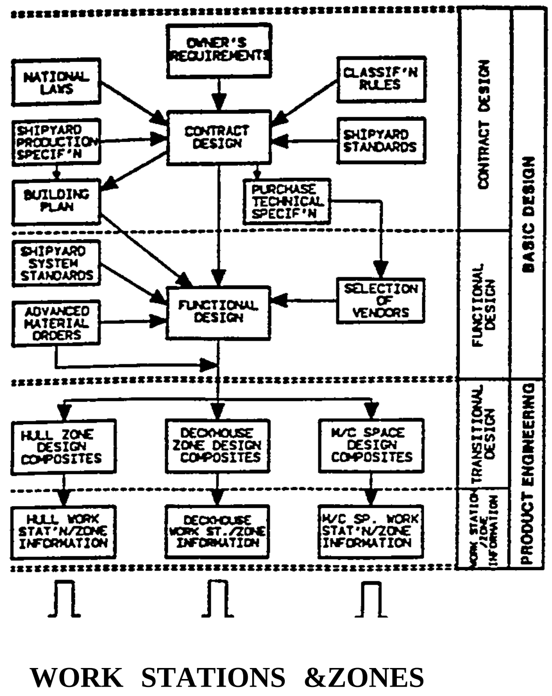


Fig. 2 Flow of design and engineering information

Production-compatible engineering

The first break from the traditional systems drawings occurred when some shipyards introduced structural module drawings. The next stage was the use of subassembly, assembly, and module-sequenced drawings, but these were initially prepared in addition to the structural module drawings. Next, pipe sketches or drawings for pipe assemblies were prepared by engineering, first manually and later by computer-aided design. Currently computer-aided design/computer-aided manufacturing is being used to provide production information for bothh pipe and sheet metal products. Today the goal for optimum data transmittal is to have an engineering information package for each work station (including zones on board the ship). This is not only for structure, but for all other material and equipment. A work station drawing shows all the work that occurs at one location, either shop or ship zone. It can be one sheet showing the completed product at the end of all work at a given work station with written sequence instructions, or it can be a booklet of drawings showing the sequenced buildup for the product from its received status to its completed status for the work station.

The Maritime Administration (MarAd)/SNAME Ship Production Committee Japanese Technology Transfer efforts have resulted in a generally accepted work breakdown structure for design and engineering [1].[2] The proposed integrated engineering approach follows this generally accepted structure, except that basic design also includes functional design, and the term product engineering covers transitional design and work instruction design. The proposed approach suggests that the design/engineeri,ng process can be conveniently divided into basic design and product engineering. Figure 2 shows the meaning of the different terms as well as the flow of the design and engineering information.

Both basic design and product engineering are further subdivided into' concept, preliminary, contract and funcional design, and transitional design and work station/mne information respectively. In basic design, all phases except functional design must be completed before the award of a contract. Functional design is the phase where the contract design is expanded to encompass all design calculations, drawings, and decisions.

Product engineering covers all tasks required to prepare the technical information to be transmitted to production and other shipyard groups to assist and direct the construction of the ship. It is divided into two phases. The first, transitional design, is the task of integrating all design information into complete zone design arrangements and to complete the ordering/assigning of all materials. The second, work station/zone information preparation, is the task of providing all drawings, sketches, parts lists, process instructions, and production aids (such as numerical control [N/C] tape for plate burning/marking and pipe fabrication) required by production and other service departments to construct the ship.

Throughout basic design, the tasks are accomplished on a system basis, whereas throughout product engineering, the tasks are accomplished on a zone basis for transitional design and a work station/zone basis for work station/zone information.

This process of design and engineering is integrated with construction planning and is in constant participation and communication with the production department. This integration can be seen in Fig. 3, which shows the process flow during contract and functional design. Figure 4 shows the process flow during transitional design and work station/ zone information preparation. It should be noted that all planning is completed during contract and functional design and in the proposed approach this includes advanced outfitting planning.

Zone construction, including advanced outfitting installation, requires engineering for the outfitting and machinery to be available at the same time as the structure. In fact, the installation of piping. ventilation ducting, ladders, mooring fittings, equipment foundations. and wireway supports should be accomplished on flat panels and/or three-dimensional modules, along with iterm of equipment such as auxiliary and deck machinery.

The shipyard production specification and building plan are essential to the proposed engineering approach. Reference [2] is a good description of the development of a building plan. The approach is also based on the use of zone construction. It is further beneficial if all manufactured and purchased material to construct the ship is categorized within a standard classification sysem (product definition). If the production methods to be used (product processes) are defined, work stations can be decided. All this information will be contained in the shipyard production specifications to be used by engineers and planners when preparing the contract design and the building plan. The product definition can be based on a group technology classification and coding system such as the one described in reference [3], or it can be a simple listing of major products as shown in Table 1. The product processes will be based on a process analysis for each product and the available work stations.

The proposed methods of preparing engineering data can actually reduce the hours for for structural engineering, but will increase all the other areas by up to 30 percent, except for piping engineering. which can increase up to 50 percent depending on the extent of the traditional engineering it replaces. The use of computer-aided design can reduce the structural and piping engineering.

However, the overall increase in engineering man-hours to accomplish the proposed work should be less than 20 per-

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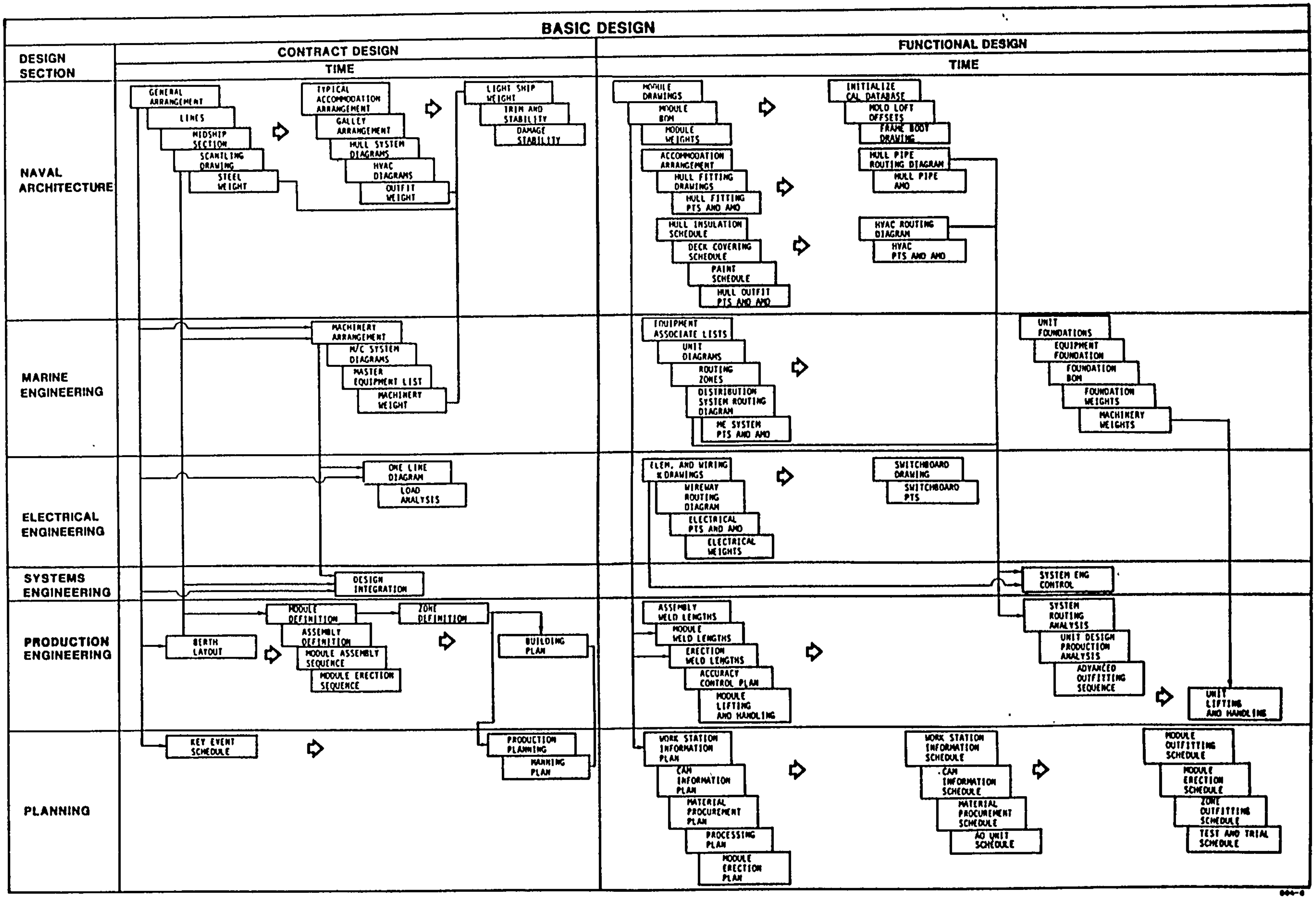


Fig. 3 Basic design flow

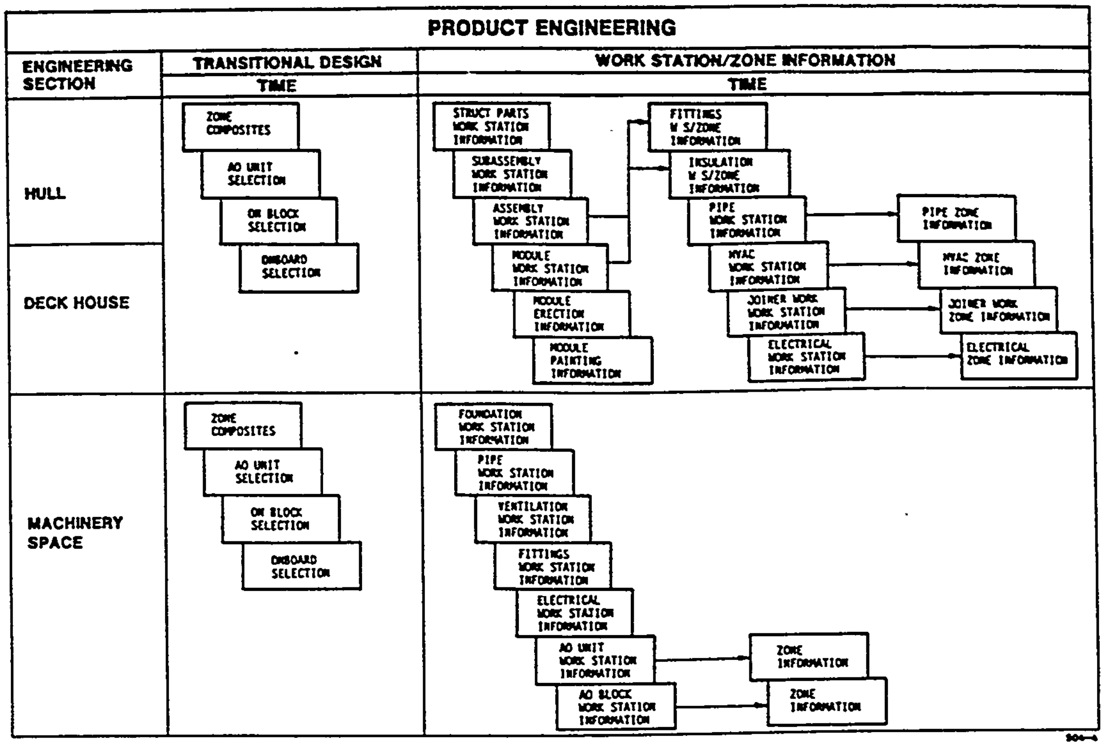


Fig. 4 Product engineering flow

Table 1 Typical product definitions

PRODUCT DEFINITION		
CODE	NAME	EXAMPLES
PL 1	PLATE PART	FLAT 1, SHAPED 2, FLAT NOTCHED 3
S 1	SECTION PART	STRAIGHT 1, SHAPED 2
SA 1	SUB-ASSEMBLY	FLAT 1, SHAPED 2, FLOOR 3, GIRDER 4
A 1	ASSEMBLY	FLAT 1, SHAPED 2
M 1	MODULE	DOUBLE BOTTOM 1, WING TANK 2, DECK WITH HATCH 3
P 1	PIPE	STRAIGHT P 11, BENT P 12
PT 1	PIPE TEE	
PV 1	PIPE VALVE	
PF 1	PIPE FLANGE	
PA 1	PIPE ASSEMBLY	

cent for a commercial vessel. In return for this additional effort by engineering, production man-hours should be reduced by 20 to 30 percent. It is easy to see that this is a worthwhile tradeoff. Table 2 gives an overview comparison between traditional and production-compatible engineering.

Suggestions on how engineering can best be provided to the production department will be presented for each of the individual groups within the engineering department, even though it is obvious that standardization of data preparation is the ultimate goal. With this in mind, it is surprising how many different drawing scales are used by different groups in the engineering department. There is really no need for more than two scales for each project. This is more significant when computer-aided drawings are utilized as the basis for, or start of, all other drawings. It also assists interference control if all drawings are to the same scale.

Basic design

General

Basic design covers all design from conceptual to at least contract design. It is proposed that it should also cover functional design. In that way, after the award of a contract, all design to define systems and required material would be part of basic design. This would keep the responsibility of contract design work within the same group.

The development of experience and skills could then be easily integrated into future contract designs. However, the main reason to include functional design in basic design is the concept that when functional design is completed, and the work tasks move on to product engineering, all design calculations, vendor selection, and system design (including system sizing, routing, and grouping) will be completed. Also, all planning would be developed parallel with basic design.

Table 2 Comparison of traditional and zone engineering

TRADITIONAL	ZONE	BENEFIT
Structural drawings prepared on item basis from bow to stern, eg, °Shell drawing °Deck drawing °Bulkhead drawing °Tank top drawing °Framing drawing	Structural drawings prepared on a construction sequence basis for subassemblies, assemblies, and modules, eg, °Web frame subassembly °Transverse bulkhead assembly °Double bottom module °Wing tank module	1. With traditional approach, construction cannot be started until a number of item drawings are complete. For example, one module required 13 drawings to be completed before module could be lofted. With zone approach, construction can commence when the first module drawing is complete. 2. With traditional approach, it is necessary for someone (production planning) to prepare module parts lists and sequence assembly sketches. With zone approach, production can use engineering-prepared drawings directly, thus saving additional effort and time.
Machinery arrangements laid out for individual equipment and piping installation.	Machinery arrangements laid out for on-unit advanced outfitting packages and piping and grating package assemblies.	On-unit advanced outfitting has been demonstrated to be the greatest productivity improver. Also allows work to be performed on unit and the ship to be completed earlier.
System diagrammatics prepared for design use only in preparation of A&D drawings with no particular accuracy in equipment location or pipe routing.	System diagrammatics prepared accurately as possible, including scheming for pipe routing with other systems and showing all information required for material procurement and planning.	1. By integrating all system diagrammatics in a given space, the grouping for piping of various systems can be considered. 2. Also, knowing that the diagrammatics are more accurate allows material to be ordered with greater confidence which reduces the need for margins. 3. More complete diagrammatics are acceptable for complete owner and classification approval, ie, it is not necessary to send A&D drawings for approval.
A&D system drawings prepared for complete ship or areas of ship without regard to module breakdown or on-unit advance outfitting. Usually prepared as independent drawings for each system, thus making integration and grouping of piping and supports together for installation difficult, if not impossible.	System working drawings consist of final instructions to the production worker, such as spool sheets, installation sketches, and material lists suitable for direct incorporation in work packages.	1. Elimination of traditional A&D system drawings. 2. Earlier availability of construction information for piping. 3. Prepared on a zone basis, earlier installation of piping. 4. Eliminates current additional step which can introduce human error and can mushroom due to unexpected interferences and/or rework.
Engineering drawings, data, etc, that are unsuitable for direct issue to production, must be further processed by production planning.	Engineering prepares all production-required drawings and data, such as structural subassembly, assembly, and module sequencing sketches; pipe spool sketches; advanced outfitting drawings and lists.	1. Elimination of some engineering effort resulting in time savings. 2. Cost savings due to eliminated effort. 3. Increase in mutual engineering/production knowledge and cooperation. 4. More problems solved on paper rather than on hardware.
No input for advanced outfitting.	Prepares advanced outfitting drawings and parts lists.	1. Engineering designs ship to facilitate advanced outfitting. 2. Forces material definition to support advanced outfitting. 3. Results in a more integrated ship.
Lofting is prepared from and therefore after detailed structural drawing is completed.	Lofting is an integrated part of structural development. Usual detailed drawings eliminated.	1. Shortened time from contract award to cutting steel. 2. Increased productivity of combined engineering and lofting.
Independent planning and scheduling keyed to a master event schedule.	Integrated planning and scheduling for engineering, material procurement, and production for individual work packages.	1. Compatibility of all detailed schedules. 2. Effect of change on one department automatically apparent to other departments. 3. Schedule items identifiable to simplest production package.

In basic design, the division of the task can follow the traditional breakdown into naval architecture, marine engineering, and electrical engineering. Some shipyards may also have designated system engineering and production engineering functions. This division is not being recommended, but is discussed and shown in Fig. 3 to identify necessary functions. Naval architecture, marine engineering, and electrical engineering responsibilities should be integrated and handled as normal necessary tasks. Some of the tasks shown under production engineering may be handled by planning rather than the basic design group.

Design for Ship Production must be applied during basic

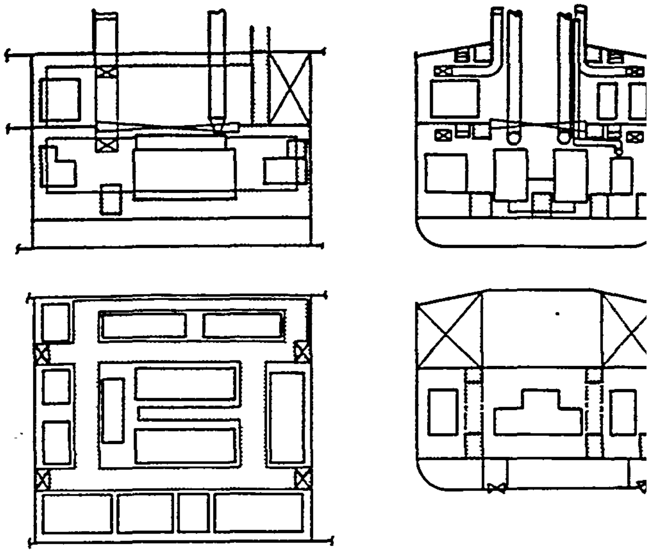


Fig. 5 Space allocation

design. As seen in Figure 3, the structural breakdown definition as well as zone and advanced outfitting 'on unit," "on block: and "on board" definitions must be decided during this phase. The building plan, finalized for its initial issue at the end of the contract design phase, will be continuously developed parallel to the preparation of functional design.

The concept and preliminary design process is well known and documented elsewhere [4-81. Therefore, no further discussion will be given. However, it is emphasized that Design for Ship Production should be incorporated into these phases of design.

Contract design and the various disciplines of functional design, as well as the impact of regulatory and classification rules and owners' requirements, will be described in the context of proposed Engineering for Ship Production.

Contract design

The 1930 Maritime Bill required that shipowners requesting government financial assistance to construct new vessels had to submit preliminary data for the intended vessels and trade route. If MarAd approved the preliminary request, the shipowner had to submit a contract design package consisting of drawings and specifications to MarAd for review and approval. MarAd then sent the package to interested shipbuilders who in turn submitted their bids to MarAd.

Understandably, shipbuilders were unwilling to spend time preparing contract designs because there was no guarantee they would be the lowest bidder when the design was sent out for bid. Thus, contract designs were mostly prepared by marine consultants. Although this system has produced many fine and successful ship types, it has a number of significant disadvantages, which can be understood by reviewing the list of documents required by MarAd. Many of the drawings define basic construction and installation details which the shipbuilder must follow. When this is done, it is difficult to take full advantage of any particular shipyard's production facilities and methods since it is not known at the time which shipyard will be the successful bidder. If the shipyard has developed standard details to suit its facilities. then prior to bid, it must either request to use its own standards or else add extra cost to deal with a nonstandard vessel. Of course, the shipyard could bid based on its standard, and then hope the shipowner will accept the standards if it is the successful lowest bidder. As an attempt to relieve this problem, consultants list certain plans as contract guidance plans in the contract spcifications. If a drawing is for guidance only, then it is not really required, and it would be more economical to eliminate it. In most cases, a special requirement can be adequately covered by a description or a simple sketch in the contract specifications.

The 1970 Maritime Bill introduced the negotiated contract. This development permitted shipowners and shipbuilders to combine efforts to design and construct the most economical vessel the shipyard could build to meet the shipowner's requirements. This approach had some early successes, but mainly for bulk carriers and oil tankers. A number of shipyards without in-house design capabilities started to buildup this capability. Unfortunately, the Arab oil embargo eliminated the U.S. tanker boom, and the general work recession has reduced the growth of world trade. Therefore, the demand for new vessel construction in the U.S. has fallen far short of the expectations of the early 1970's. The economic fact of no work and no need for in-house designers stopped shipyard design group growth, and most new designs are again being prepared by consultants.

Parallel to this commercial ship development, the U.S. Navy up until recently had its own in-house design staff who prepared contract designs for all naval ships. Initially, this changed to having marine consultants prepare the contract designs for a Navy design program group, and then to shipbuilder-prepared contract designs based on a Navy-prepared Technical Requirements Document. In the latter case, the shipbuilder usually used marine consultants to prepare or at least assist them to prepare the contract design.

One way to achieve a minimum cost U.S. shipbuilding industry is to reduce the number and detail of contract design plans prepared by a consultant for an owner or the U.S. Navy. A contract lines plan should only be provided if the model tank tests have been run as part of the contract design. If the model tank tests are to be run by the shipbuilder, or if the shipbuilder is contractually responsible for the trial speed, only a preliminary plan need be prepared showing body plan and bow and stem profiles **[91.**

In the past, many commercial contract designs were submitted to the classification societies and regulatory bodies for approval before they were released to the shipyarda for bidding. While some shipyards may like the apparent insurance of knowing that contract documents are approved by such organizations, this is only necessary for novel design concepts and not for normal modem ships. By eliminating this step, the contract design package could be in the hands of the shipbuilder at least two months earlier. If these two months were given to the shipbuilder as additional time to prepare the bid, a better bid could be submitted, thus ensuring the most competitive prices. It would also give the successful low-bid shipyard the responsibility of getting the design details approved as early as possible by its regional approval office. This is so important because often when consultants get approval of contract plans. they are approved in New York or Washington. D.C. The shipyard developing the plans proceeds assuming everything is in order, until it is quickly brought back to reality when the regional ofice disapproves details based on headquarter's approved contract design.

If the contract design is prepared by the shipbuilder, the basic planning for design of the machinery space should be performed. When locating the propulsion machinery. the space needed for units, pipe/system corridors, and working space should be taken into account as shown in Fig. 5. This is where the use of standards, such as standard machinery space ar-

rangements, system units, or system corridors, pays off. This approach also enables a quick check on space requirements before the design has progressed too far. The module definition should also be prepared either for an in-house contract design or as a bid preparation document for an owner-prepared contract design.

Classification and regulatory organization requirements

For commercial ships, the drawings that must be sent to the classification society and the regulatory body to obtain their approval and certificates for the vessel are listed in the roles and regulations of those organizations. It is unusual to prepare drawings exactly matching the lists, but the intent is all that need be followed.

The normal practice of submitting the shipyard's proposed drawing list to various *organizations for* approval achieves a useful end result, but often results in orgnizations requesting drawings they really do not need. In the past, many drawings were really shop detail and duplicated information shown on other general drawings. Every attempt should be made to keep shop detail and instructions out of the drawing list and therefore the approval cycle. For example, some shipyards prepare work station drawings for each structural assembly in addition to the complete structural module drawings. The structural module drawings are approved, but the shipyard still sends the assembly work station drawings for approval, which is completely unnecessary. The American Bureau of Shipping (ABS) has indicated it would rather not receive the assembly drawings. However, if a drawing is submitted, it must be reviewed and approved by the ABS. The concept of approving a detail only once should be the guide on when a drawing should be submited to external organizations for approval *or record* and what is simply more detailed shop instructions of the same data and should be kept in-house. In the proposed approach, this is conveniently accomplished by only submitting functional design data. It is an obvious requirement that work station instructions should be given to the resident owner and other inspectors to assist them in their work.

In this country, the U.S. Coast Guard accepts hull drawings after they have been approved by ABS. The ABS also approves machinery drawings for the Coast Guard. This procedure is beneficial to all concerned and compliments the above suggestions.

Many preparers of engineering data leave necessary information off design drawings and diagrammatics, knowing that detailed drawings will be submitted later. However, it is better to provide *all* the information required for approval on the drawings and diagrammatic, even though it requires more detail and greater accuracy. Complete diagrammatic with piping shown in the correct location and all materials and equipment specified should be provided. Both the U.S. Coast Guard and ABS have agreed to accept complete and accurate piping diagrammatics as fulI submittal for most piping systems. It is not necessary to prepare a piping arrangement and detail plan for classification and regulatory body approval. Again, the proposed approach is that the functional design group completes all design and provides information as desired by the classification and regulatory bodies.

Owner engineering requirements

The commercial shipowner has a need for the following. types of engineering information

1. The same drawings as required by classification and regulatory organizations. The shipowner needs them as a record of approval from the various organizations and as a means of checking to see that the vessel the shipbuilder plans to build is the one under contract. This verification is accomplished by approving drawings prior to construction and using them to inspect the work under construction. These drawings will also be a final record kept on board as information that may be needed by the ship's crew.

2. Selected shipbuilder constriction drawings that may be required by the owner to repair, convert, and/or upgrade the ship throughout its life.

3. Special drawings and data not used by the shipbuilder but necessary for the ship operator, such as:

- capacity plan,
- firefighting arrangements,
- trim and stability booklet,
- damage stabiIity booklet,
- safety plan (fire and lifesaving),
- tank sounding tables, and
- ship operating manual.

Although some shipyard product engineering data could be useful to a ship repairer in the event of damage to ship structure or systems, it is not essential, and therefore would not be provided as a normal part of the data package to the shipowner. However, the owner could be advised to obtain from the shipyard any data such as structural material lists, N/C tapes, or piping shop sketches in the event they are needed for future repairs or upgrading the ship.

. The shipowner also requires data lists, equipment manuals, and any other special instructional data necessary to enable safe and proper operation of the ship.

The engineering requirements for the U.S. Navy are different in a number of respects from those of the commercial shipowner. These requirements are cIearIy defined in the "General Specifications for Ships of the U.S. Navy and various Department of Defense standards. These requirements are unique due to follow-on shipbuilder, integrated logistics support, reliability and maintenance, standardization, and many *other* aspects of naval ships. Since these detailed requirements are based on past practice, it is not surprising they are incompatible with the proposed Engineering for Ship Production approach. Therefore, it is necessary for the ship builder to present in detail how the *"intent"* of U.S. Navy requirements will be met in the bid proposal, while allowing the proposed approach to be used and thus achieving benefits to both the shipbuilder and the U.S. Navy.

Structural **functional** design

In most shipyards today, no production worker or even supervisor is involved in all stages of processing the hull structure from raw material to erection on the berth. Therefore, the practice of preparing a very detailed structural drawing indicating all the information needed for lofting, cutting, processing, subassembling, module construction, and erection is not an efficient method. Past practices coupled with the still-used method of preparing construction structural drawings as complete item drawings (such as deck plan and bulkhead plan) *results* in a *system* that can *only* lead to confusion when any structural subassembly or module construction is attempted. Instead, functional design sructural drawings should be prepared for each module. Steel ordering takeoffs should also be prepared on a modular basis. This is basic, but very important. A typical structural module drawing is shown in Fig. 6. Such drawings show all the structure and details necessary to prepare product engineering for the module. Standard structural detail and ship welding booklets could be used by product engineering to prepare the module work station information and by loftsmen to loft the structural parts.

The following example is one obvious indicator of how this approach simplifies understanding the job to be done compared to traditional engineering. To construct a typical module, 13 structural drawings *were* needed, whereas obviously

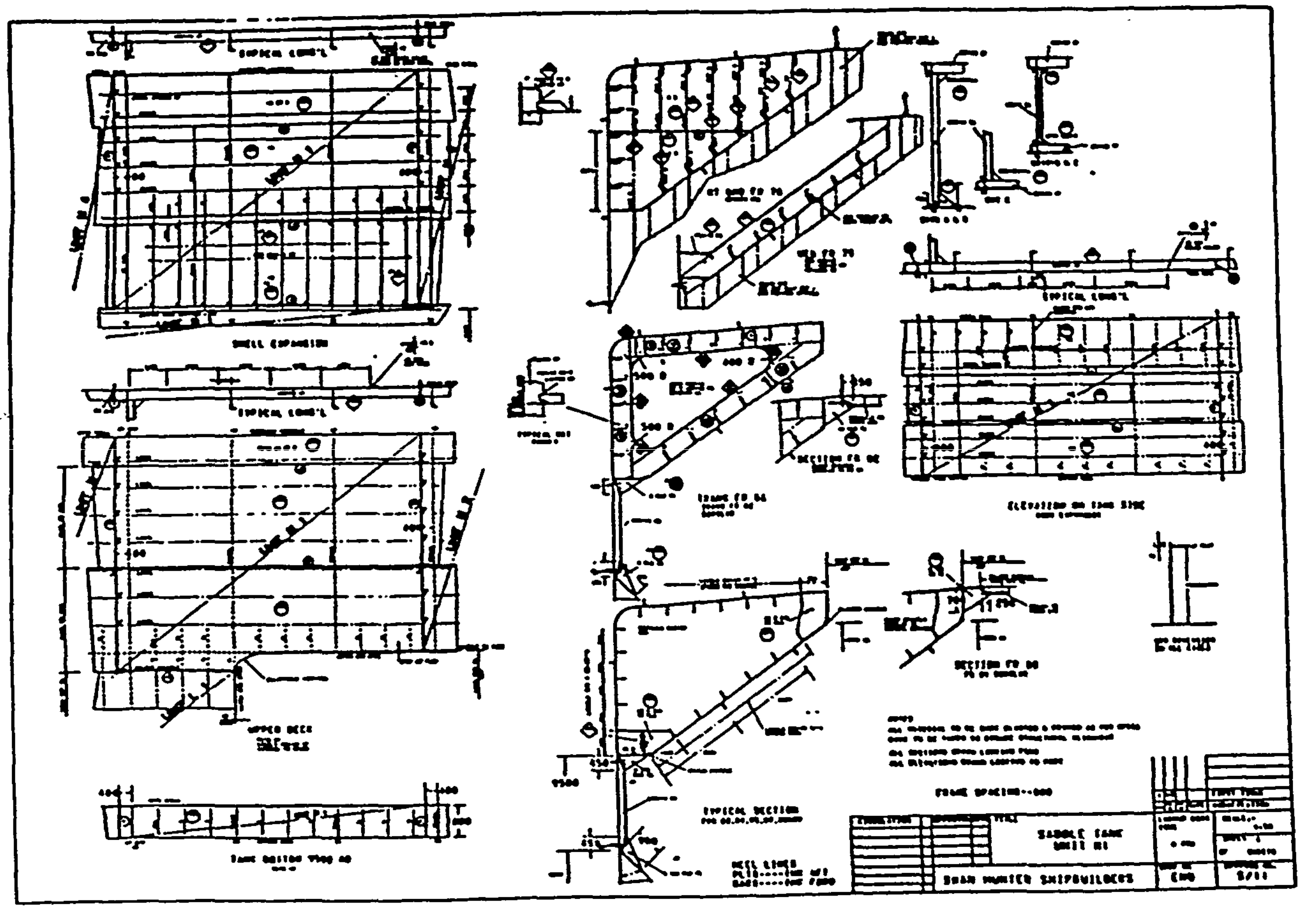


Fig. 6 Structural module drawing

only one structural module drawing would have been *re*quired.

Another advantage of using module drawings compared to complete item structural drawings is the simplification of the part numbering system. For example, consider a complete deck structural drawing. If the part numbering system consists of the drawing number and a sequential number, considerable effort must be used to group the parts in special subassembly, assembly, and module lists ta help the computer-aided lofting programmer to nest parts needed for a given product and the material handlers to find the material and deliver it to the work station building the product. On the other hand, if structural drawings are prepared for each module, the part numbering can be unique to a given module, assemblies, and the subassemblies. That is, the part number will be the module/assembly/subassembly numbers and a sequential number for each. The above-mentioned problems simply disappear with this approach. Also, sequential numbers are smaller since they start with one for each module/assembly /subassembly. This obviously helps marking the individual **parts, especially** if they are small.

The engineering information prepared for the modular approach must be complete and accurate compared to traditional practice. Before, the designer could leave some details to be resolved by the loft. Now this is no longer acceptable.

The usual practice of preparing the lofting from the structural drawings should be changed. Most shipyards today utilize computer-aided lofting (CAL). The initialization of the CAL database should be commenced as soon as possible. This includes CAL fairing of the lines, interior and shell traces, butts and seams, etc. As a minimum, the CAL system can then be used to provide the basic structural module drawing backgrounds. Many shipyards are using computer-aided design (CAD) systems which are linked with the CAL system. In that case, the drawing database and the CAL database are ideally one and the same or at least developed parallel and from each other. The lofting is then effectively developed along with the design, and is turned over to product engineering for retrieval of computer-aided manufacturing (CAM) data to process structural parts. Such an approach results in significant reduction in engineering/lofting manhours due to the logical and hierarchical development of the detailed parts. This can be contrasted with the lofting-after-engineering approach, where even with module structural drawings, the CAL programmed are inclined to program each drawing separately. This, in turn, requires additional part programming and checking as well as extra effort to check that interfacing parts shown on different drawings are compatible. Another advantage of using a single-database CAD and CAL system is that the drawings will show details of the structure as they will be actually cut and processed. This obviously assists in interference avoidance and control, especially if all penetrations are programmed into the database and cut by the N/C burning machine.

Hull outfit functional design

Hull outfit functional design consists of developing all the details for the outfit design and completing the definition of all outfit material. Again the use of standards reduces the effort. Also, ship standard details should be completed for

issue to the product. engineering section. A very large part of hull outfit functionaldesign consists of preparing purchase technical specifications for the required equipment and advanced material ordering. If the contract design for the ship is not prepared by the shipyard, considerable effort will be required to prepare accommodation layouts.

Marine engineering functional design

Engineering for Ship Production places more responsibility and output demands on the marine engineering functional design than does traditional engineering because all design calculations. as well as system diagrammatic.a must be completed in this phase. The location of the machinery, units, system corridors, and working space will have been prepared for the contract design. In developing the functional design, contract design marine engineering is effectively checked. Any standards selected in the contract design phase are considered in greater detail and the design capacity confirmed. The system diagrammatics must be prepared showing distribution in the assigned system corridors and must be sized and show required flow information.

To accomplish this task, a distributive system routing diagrammatic for the machinery space should be developed as shown in Fig. 7. The pipe, electrical, and HVAC systems must be located within their distribution corridors, and corridor sectional cuts are very helpful for control. The master routing diagrammatic would become the basis for the transitional design phase zone design arrangements. All machinery purchase technical specifications would be prepared during this phase. As the system diagrammatic are completed, advance ordering of pipe, valves, fittings, sheet metal for vent duct, etc. should be performed. Vendor selection and vendor plan approval should also be completed.

Electrical engineering functional design

Again, all design calculations and distribution wiring diagrammatic (elementary and isometric or block drawings) should be completed during the functional design phase. The wiring diagrammatic should be routed in assigned wireway corridors with the cable size and type shown. If standard machinery units, accommodation units, etc, are used, the wiring diagrammatic should simply consist of distribution design to the standard units. The distribution design should take into account the modular breakdown, zone definition, and extent of advanced outfitting before erecting and joining modules. For example, Fig. 8 shows two possible ways to arrange electrical system distribution. For passenger ships, warships, and multideck cargo ships, vertical distribution within each module is best for production and from the damage control aspect. For a bulk earner or tanker, there is no choice, and horizontal distribution is used. Again, all purchase technical specifications and advanced material ordering should be prepared.

System and production engineering

It is preferable to integrate both systems engineering and production engineering into the three basic design disciplines than to have separate specialist groups. However, for this to occur, it is necessary to know what the functions entail.

Systems engineering is an organized approach to the interaction between the parts of a system (such as a unit, a machinery space, a deckhouse, or a complete ship). It is based on two concepts. namely:

1. The interconnections the compatibility, the effect of one upon the other. the objectives of the whole system, the relationship of the system to the users, and the economic feasibility must receive even more attention than the parts, if the complete system is to be more successful.

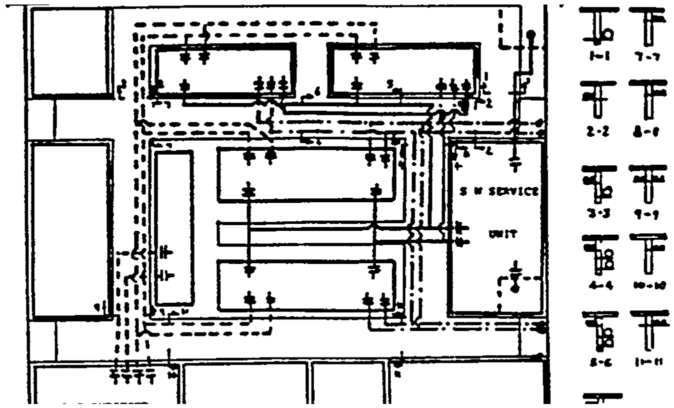


Fig. 7 Distributive system routing diagram

2. The ever-increasing degree of specialization requires a formal integration of the specialist parts to ensure that the overall objective solution is the best and most economical.

The tools of system engineering consist of systems theory, systems analysis, computer processing aids, operations research, decision concepts, and statistical decision theory.

Therefore, design engineers must become familiar with these tools so that the integration of systems engineering with traditional shipbuilding engineering can be effectively accomplished. The role systems engineering plays in Engineering for Ship Production is to ensure that the various ship systems are well-integrated and offer the best possible design and construction cost.

Production engineering and industrial engineering are synonymous. They can be defined as the task of determining the best methods for performing the various manufacturing processes within a given facility, taking into account its limitations and operational goals. The functions of production engineering are:

- product definition,
- process analysis,
- process planning,
- value engineenng,
- work and method study,
- machine and tool requirements,
- process information and instruction requirements. and
- link between engineering and production depamments.

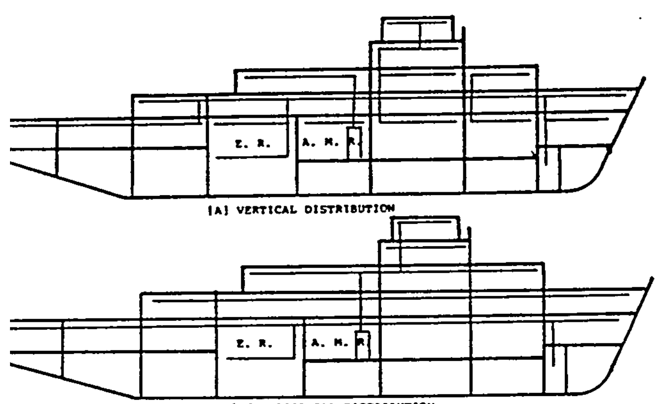


Fig. 8 Electrical system distribution

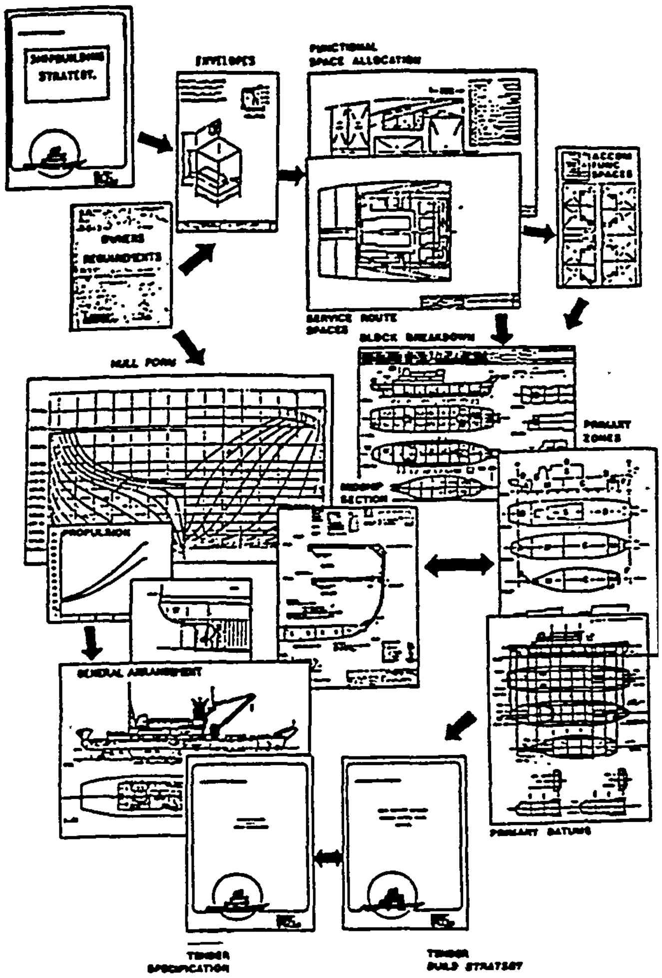


Fig. 9 Integration of production engineering and contract design

For further discussion on the application of production engineering to shipbuilding, a number of technical papers are recommended [10-13]. The production engineering function can be shared, in part, between engineering and planning. However, industrial engineering tasks, such as work measurement and method study, require specialist training and experience.

In performing the production engineering function, decisions should be made on module definition, zone definition, assembly and construction approach, and advanced outfitting approach.

These decisions should be made before the functional design is begun. This is important because the application of production engineering during contract design makes possible the lowest cost design. If production engineering is ap plied after the completion of contract design, it will probably result in design changes to achieve low cost, but will have wasted time and design effort (cost). Production engineering decisions should become part of the building plan as shown in Fig. 9, which is based on a figure from reference [13].

An effective production engineering tool is the product/stage chart shown in Fig. 10, which is based on a similar chart developed by A&P Appledore. From such charts, the sequencing of the various products that go into a module. zone, or onto a unit can be better understood and planned.

The module definition could be based on a structural product breakdown structure such as the *one shown in* Fig. 11. The zone definition can be similarly based on a zone breakdown structure as shown in Fig. 12. Both breakdown structures are integrated in Fig. 13.

Product engineering

Transitional design

The transitional design can be likened to building a prototype, except that it is constructed on paper. If CAD is used, the prototype is effectively modeled in the computer. The most important task in transitional design is the selection of the zone/subzone breakdown for the design effort. As a guide, a subzone could be a compartment sumounded on all sides by major structural divisions, such as deck/flat/tank top, transverse bulkheads, side shell, and longitudinal bulkheads.

Zone design arrangements are similar to the traditional composites. However, they are prepared from distribution system routing diagrammatic developd during functional design. The traditional composites are prepared from completed system arrangement and detail drawings. Traditional composites are drawn as an interference checking tool and, for this purpose, are slices through the compartment, showing only the items in the immediate layer below. Zone design arrangements show all the visible items seen from the vewing plane. All products should be included no matter how small. The traditional composite practice of excluding pipe below $1\frac{1}{2}$ in. diameter (3.8 cm) is no longer acceptable. When the zone design arrangement are prepared manually, the backgrounds can be provided by the CAL system. Menually prepared zone design *arrangements* could be drawn with single line pipe representation. However, it is preferred to show double line, including insulation where appropriate. Once the zone design arrangement is completed, the products are identified as follows unit, pipe assembly, vent assembly, wireway, foundation, and floor plate group.

The required zone/unit material quantity is also developed at this time. Typical forms used for this purpose are shown in Table 3. By accumulating the material quantities as zone design arrangement are prepared and deducting the material from advance material orders, effective material ordering control is possible. A list of all the products in a zone/subzone provides an accurate compartment checkoff list.

Obviously, during the preparation of zone design arrangements, all systems are developed for interference avoidance and checked for interference as the work progresses.

It should be obvious *that* the use of CAD for this design phase has many advantages. Three-dimensional solid modeling CAD systems enable a true prototype to be modeled and all working, maintenance, and access requirements to be checked prior to any construction.

Work station/zone information

Many successful shipyards claim that their success is based on better work organization. This is accomplished through better planning and better instructions/information and work packages. The work package concept is the division of a total task into many work packages for small tasks. A usual guide is that a work package should be as follows.

1. two-week duration maximum
2. two hundred hours of work maximum:
3. work for a maximum of three workers;
4. include only (but *all)* the information required by workers to complete the work package tasks. including drawings, parts lists, and work instructions: and
5. include production aids such as N/C tapes, templates and marking tapes.

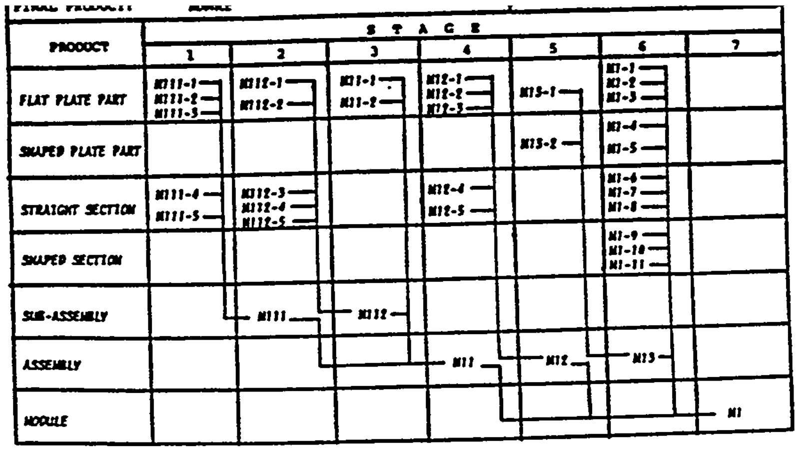


Fig. 10(a) Product/stage chart for structural module

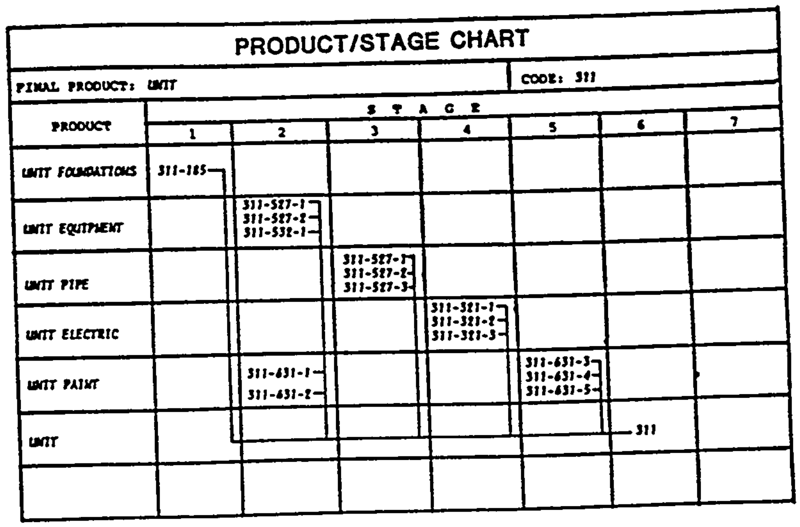


Fig. 10(b) Product/stage chart for machinery unit

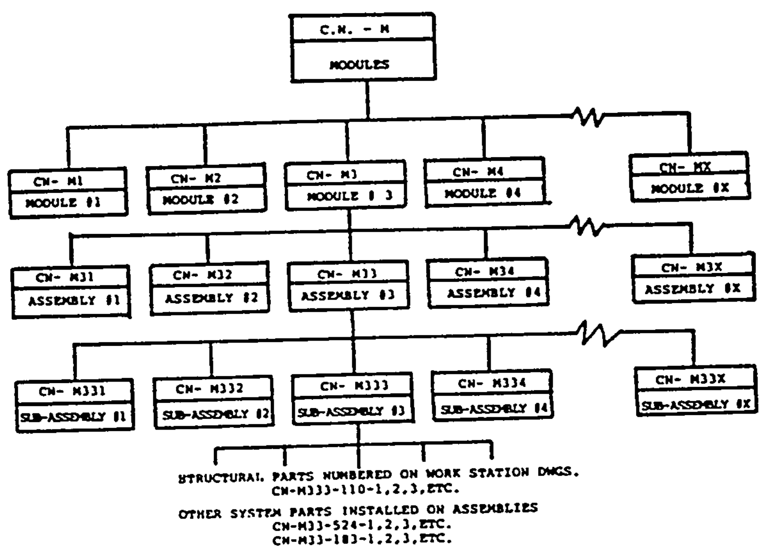


Fig. 11 Structural module breakdown

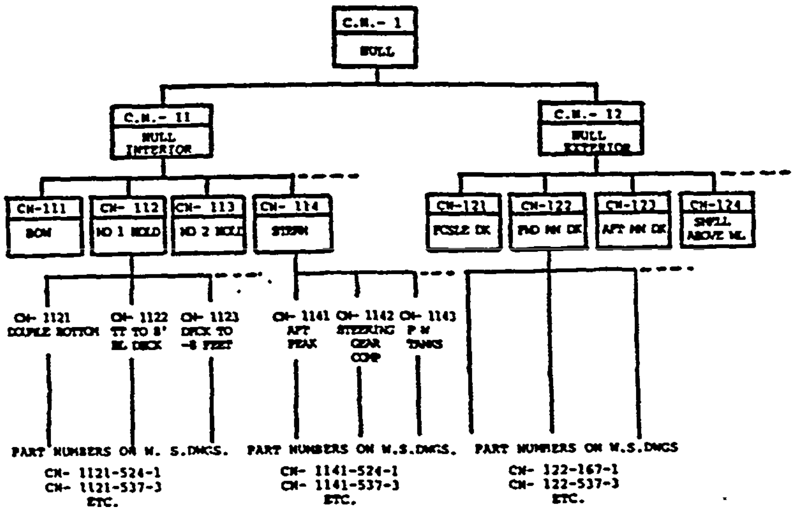


Fig. 12(*a*) Hull zone breakdown

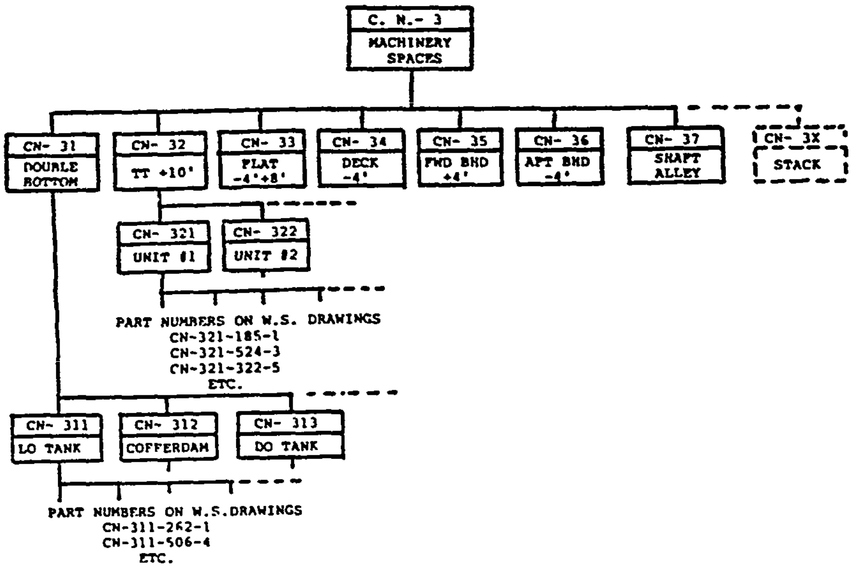


Fig. 12(*b*) Machinery space zone breakdown

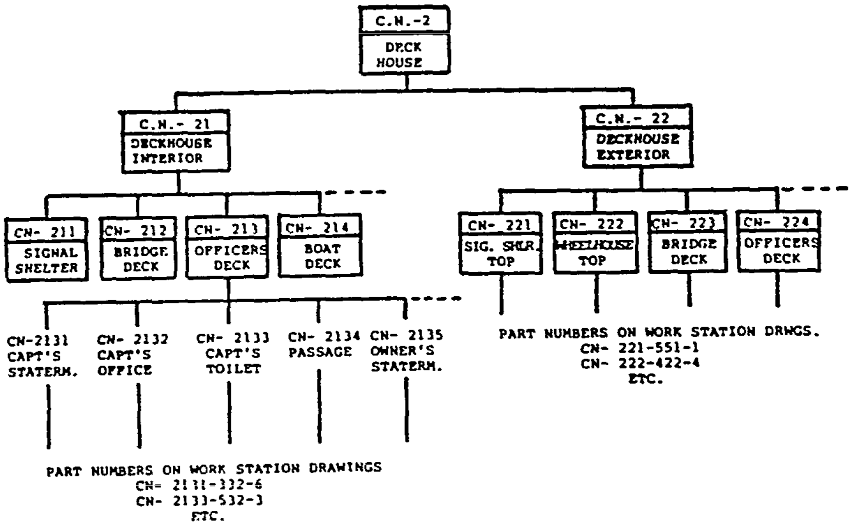


Fig. 12(*c*) Deckhouse zone breakdown

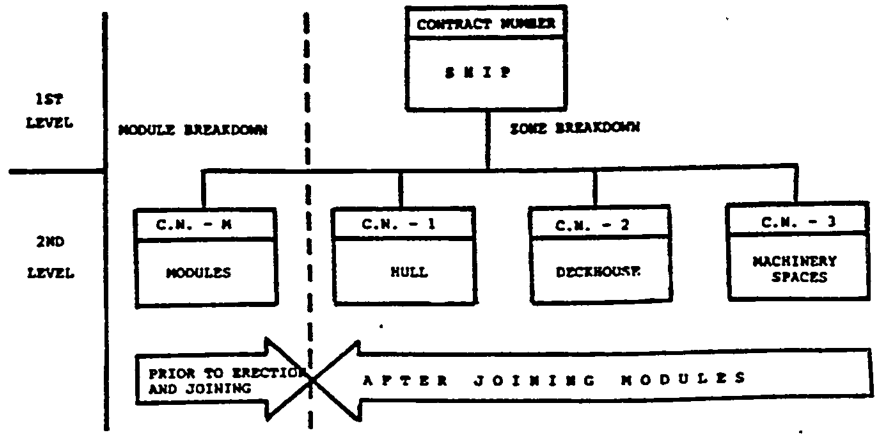


Fig. 13 Ship breakdown structure

The first three items are difficult to adhere to for certain shipbuilding tasks on the berth but are achievable for most shop work.

Engineering can effectively participate in preparing some of this information and, in doing so, eliminate a lot of current duplication of effort. Planning will select the tasks to meet the first three requirements. Engineering can prepare the information covered in the last two.

For this approach, it is proposed that separate work station information be prepared for each work package. Work station information should be prepared on the following basis:

1. Information should only show that necessary for a given work station.
2. Information should consist of sketches and parts list.
3. Complete information for the tasks must be given. No referencing allowable.
4. Separate work packages should be prepared for each craft (trade). Sketches and parts lists should not mix work that must be done by different crafts.
5. Sketches should be prepared to show work exactly as workers will see it. For equipment, piping, or other products that will be installed on an assembly when it is upside down, the sketch should be drawn that way rather than for the final attitude plan view.
6. A reference system should be used, and all dimensions should be from the reference system planes.
7. Information should be prepared so it can be issued on $8^1/_2$-by-11-in. sheets.

Structural work station information

Today most shipyards use CAL to prepare the lofting and to develop the necessary production aids for construction of the ship structure. This system eliminates the need for manual measuring and layout of plates. Therefore, the drawings used for subassembly, assembly, and module construction need not contain any dimensions other than check and quality assurance control dimensions. What is needed is a way to provide required information that is completely compatible with the way in which it will be used in various stages of construction of the structural hull and deckhouse.

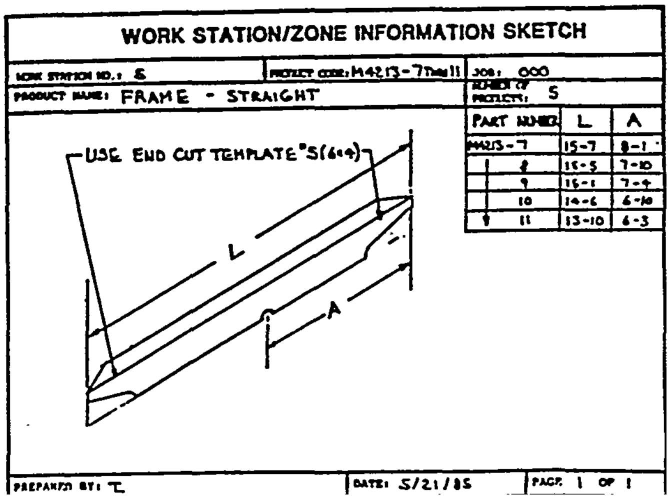
This can be effectively and efficiently accomplished by using the following data packages:

1. *For burning plate.* Nest tape sketches and N/C tapes.
2. *For cutting shapes.* Process sheets, marking tapes, and sketches.

Table 3 Zone/unit material lists

ZONE DESIGN ARRANGEMENT		ZONE NUMBER. 31	
PRODUCT. FIRE PUMP UNIT		PRODUCT NUMBER. 312	
CODE	DESCRIPTION	QUANTITY NUMBER	QUANTITY MEASURE
1453066627	Foundation	1	
	Floor	1	
	Rail	1	
	Ladder	3	
5200661004	Fire Pump 1	1	
5200661004	Fire Pump 2	1	
5280661003	Duplex Filter	2	
5228661407	Pipe Assembly 1	1	
5228661407	Pipe Assembly 2	1	
5228661407	Pipe Assembly 3	1	
5228661407	Pipe Assembly 4	1	
5228641404	Pipe Assembly 5	1	

ZONE DESIGN ARRANGEMENT		ZONE NUMBER: 31	
PRODUCT: PIPE ASSEMBLY 1		PRODUCT NUMBER: 31-527-1	
CODE	DESCRIPTION	QUANTITY NUMBER	QUANTITY MEASURE
5220461471	Pipe, 6-Inch	1	10 Feet
5220461482	Pipe, 4-Inch	1	20 Feet
5220441494	Pipe, 1-1/2-Inch	4	80 Feet
5230661463	90 Elbow, 6-Inch	2	-
5240000001	6-Inch Hanger Type I	5	-
5240000002	4-Inch Hanger Type I	7	-
5240000003	1-1/2-Inch Hanger Type I	6	-
5211100042	Gate Valve, 6-Inch	2	-
5221100032	Globe Valve, 4-Inch	4	-
5221100021	Globe Valve, 1-1/2-Inch	3	-



Fig, 14 **Structural section** process Sheet

3. *For* processing *plate* or- shapes (i.e., *bending,, flanging,* drilling). Process sheets and templates.

4. *For subassembly construction.* Subassembly drawing and parts list.

5. *For assembly construction.* Assembly drawing and parts list.

6. *For module construction.* Subassembly, assembly, and parts list, module assembly sketch, and welding sequence.

7. *For module erection.* Hull module plan, excess stock plan, rolling and lifting sketches, and welding sequence.

The advantage of structural work station information is that only the data necessary for the work being performed at a particular stage is given. There is no need to search through a number of large plans to get the necessary data. An advantage of module assembly sketches is that they enable the designer to consider access requirements for both people and machines at various construction stages. The advantage of sequence sketches is they actually show how to build the subassembly, assembly, or module. This is of great assistance to engineering, planning, production workers, and their supervisors. The preparation of sequential construction sketches requires a closer relationship with planning and production than usual. In order to correctly design a ship structure, it is necessary to know how it will be built. However, for sequential sketches, it is essential to work with planning and production to decide in considerable detail how the structure will all go together. Holes, notches, clips, and other means to facilitate the use of available manual alignment and fairing tools (such as hydraulic pullers and fairing rams) could be designed into the structure and shown by engineering on the subassembly, assembly, and module construction sketches.

Actually, this extra effort is vaIuabIe because once it is done it aids everyone involved in getting the structure constructed. Without the added effort, either planning has to prepare instructions to accomplish the same end result or it is left to the supervisor and men on the job to plan the construction sequence. With such an arrangement, the shipfitters may construct the module in a different way to that envisioned by the designer. Sometimes the parts cannot go together and modification on the job is necessary. It is better to get all the people responsible for engineering, planning, and building the structure to decade these matters at an early

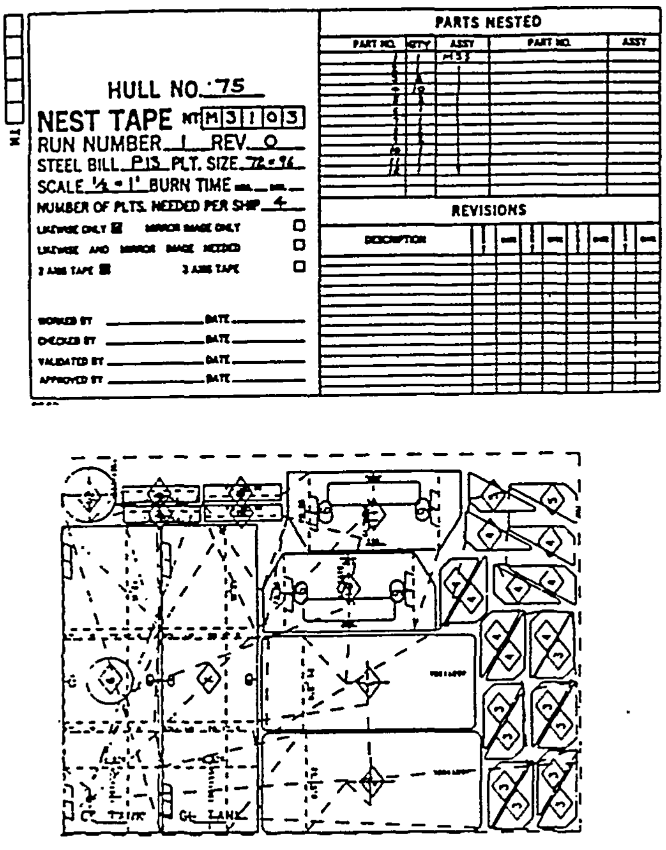


Fig. 15 Structural plate process sheet

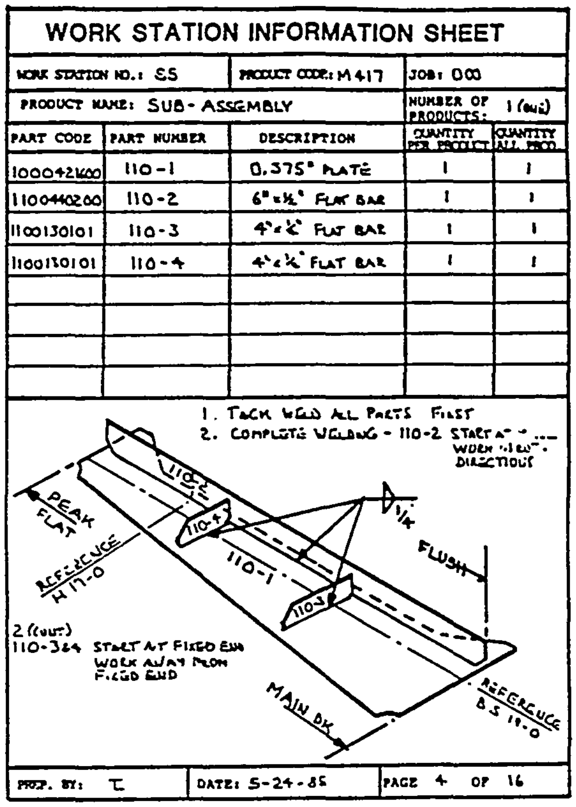


Fig. 16 Structural subassembly work station information

stage of the project and to include them in the building plan.

A typical work station information package (process sheet) for structural shapes is shown in Fig. 14. It shows the finished part for a floor stiffener and gives material total quantity required to cut all the parts listed. The package also shows the parts are of different lengths. Delivery instructions for unused material and finished parts can be included on such a drawing. Accuracy control data can also be included.

The CAL N/C plate cutting drawing with attached instruction sheet (shown in Fig. 15) is typical of a plate part work station information package.

Figures 16, 17, and 18 show the work station information packages for typical subassembly, assembly, and module, respectively. Note that for the assembly and module, the parts lists are separate from the drawings. The Parts list should be sequenced in the way the product is to be constructed. Again, the product/phase chart can be used to develop the sequencing. Figure 19 shows a typical parts list.

The work station information for joining the modules could include alignment, fitting, dimension control, accuracy control, and welding data. Figure 20 shows a typical welding work station information sheet.

It is important to remember that all the information re-

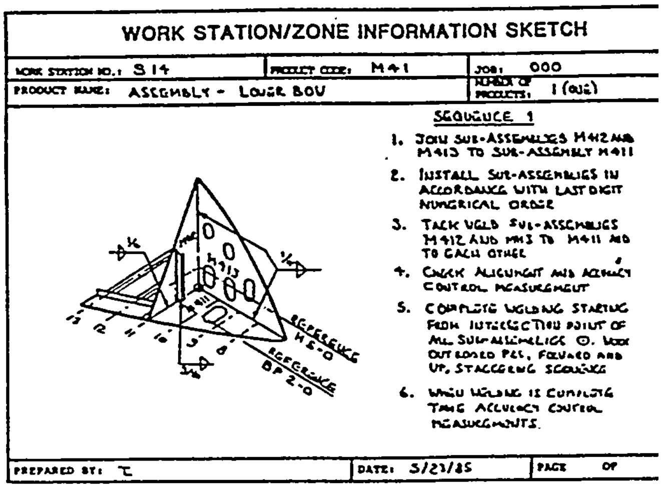


Fig. 17 Structural assembly work station information

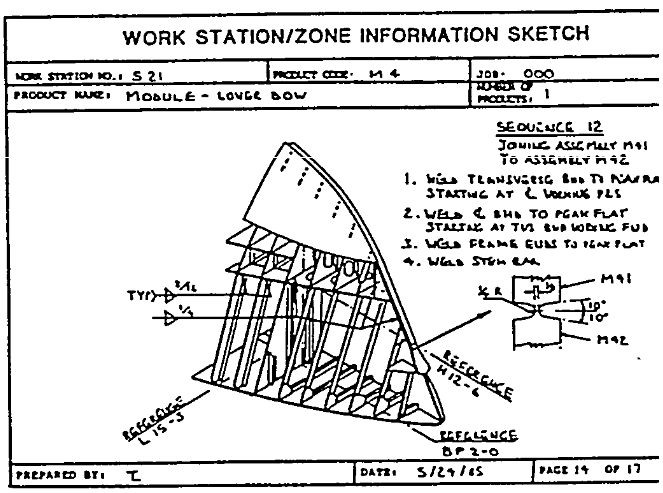


Fig. 18 Structural module work station information

WORK STATION PARTS LIST

WORK STATION NO. S 14	PRODUCT CODE: M41		JOB: 000	
PRODUCT NAME: ASSEMBLY - LOWER BOW			NUMBER OF PRODUCTS: 1 (ONE)	
PART CODE	PART NUMBER	DESCRIPTION	QUANTITY PER PROD.	QUANTITY ALL PROD.
SEQUENCE 1				
	M411	SUB-ASSEMBLY	1	1
	M412	SUB-ASSEMBLY	1	1
	M413	SUB-ASSEMBLY	1	1
SEQUENCE 2				
	M414	SUB-ASSEMBLY	1	1
	M415	SUB-ASSEMBLY	1	1
	M416	SUB-ASSEMBLY	1	1
	M417	SUB-ASSEMBLY	1	1
	M418	SUB-ASSEMBLY	1	1
	M419	SUB-ASSEMBLY	1	1
SEQUENCE 3				
	M41-1	PART	1	1
	M41-2	PART	1	1
	M41-3	PART	1	1
	M41-4	PART	1	1
SEQUENCE 4				
	M41-A	ASSEMBLY (MINOR)	1	1
SEQUENCE 5				
	M41-5	PART	1	1
	M41-6	PART	1	1
PREP. BY:	DATE:		PAGE OF	

Fig. 19 Structural assembly work station parts list

WORK STATION INFORMATION SHEET

MODULE JOINING WELDING

MODULE M4 TO M3				JOB: 000	
SEQUEN.	ITEM	TYPE OF WELD	SIZE	WELDING PROCESS	REMARKS
1	℄ BHD TO TRVS BHD	DOUBLE CONT FILLET	1/4	MANUAL	START AT MIDDLE WORK OUTWARDS
2	FLAT TO TRVS BHD	DOUBLE CONT FILLET	1/4	MANUAL	START AT ℄ WORK PES ALTERNATE
3	FLAT KEEL TO FLAT KEEL	CONTINUOUS BUTT		MANUAL	START AT ℄ WORK P&S
4	STRINGER TO STRINGER	CONTINUOUS BUTT		MANUAL	START AT SHELL
5	MAIN DECK GIRDER TO GIRDER	CONTINUOUS BUTT		MANUAL	
6	MAIN DECK TO MAIN DECK	CONTINUOUS BUTT		MANUAL / SUB ARC	UNDERSIDE / TOPSIDE
7	SHELL TO SHELL	CONTINUOUS BUTT		MANUAL	OUTSIDE FIRST THEN INSIDE

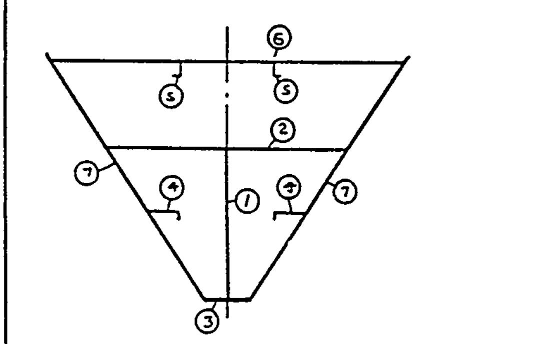


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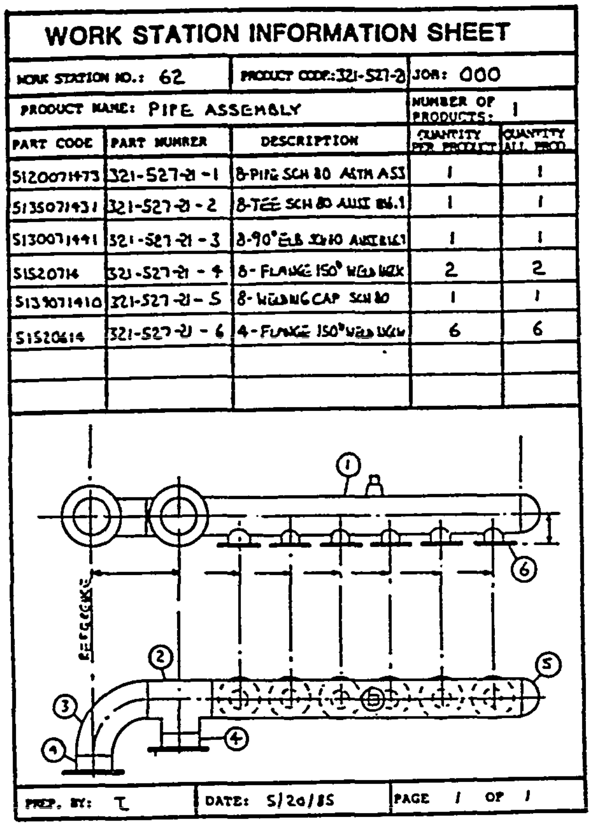
Fig. 20 Module joining welding work station information



WORK STATION INFORMATION SHEET

WORK STATION NO.: 62	PRODUCT CODE: 321-527-21	JOB: 000		
PRODUCT NAME: PIPE ASSEMBLY		NUMBER OF PRODUCTS: 1		
PART CODE	PART NUMBER	DESCRIPTION	QUANTITY PER PRODUCT	QUANTITY ALL PROD.
5120071473	321-527-21-1	8-PIPE SCH 80 ASTM A53	1	1
5135071431	321-527-21-2	8-TEE SCH 80 ANSI B16.1	1	1
5130071441	321-527-21-3	8-90° ELB SCH 80 ANSI B16.1	1	1
5152074	321-527-21-4	8-FLANGE 150# WELD NECK	2	2
5139071410	321-527-21-5	8-WELDING CAP SCH 80	1	1
5152061 4	321-527-21-6	4-FLANGE 150# WELD NECK	6	6

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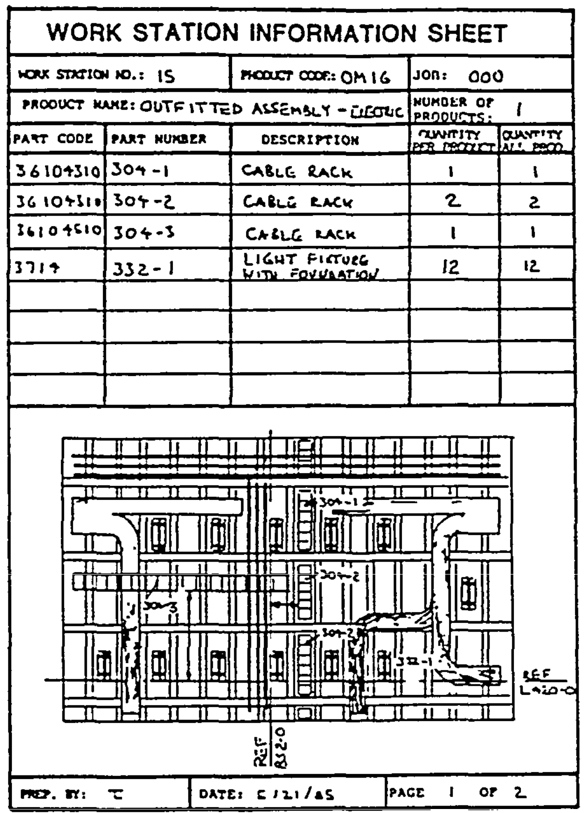
Fig. 21 Pipe assembly work station information



WORK STATION INFORMATION SHEET

WORK STATION NO.: 15	PRODUCT CODE: OM 16	JOB: 000		
PRODUCT NAME: OUTFITTED ASSEMBLY - ELECTRIC		NUMBER OF PRODUCTS: 1		
PART CODE	PART NUMBER	DESCRIPTION	QUANTITY PER PRODUCT	QUANTITY ALL PROD.
36104310	304-1	CABLE RACK	1	1
36104311	304-2	CABLE RACK	2	2
36104510	304-3	CABLE RACK	1	1
3714	332-1	LIGHT FIXTURE WITH FOUNDATION	12	12

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Fig. 22 "On block" advanced outfitting installation work station information for electrical

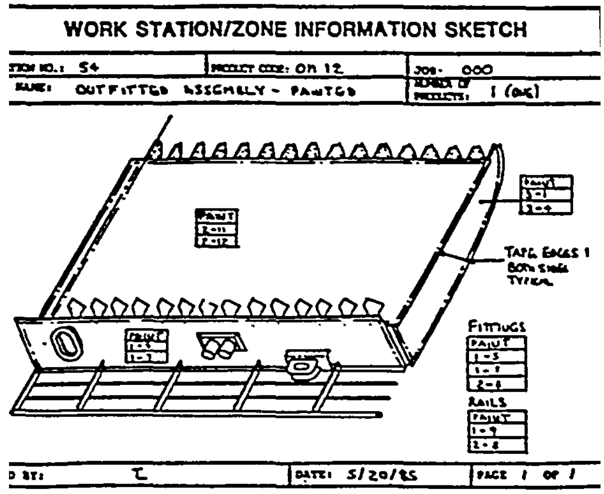


Fig. 23 Painting work station information

quired by the workers to perform a work package should be included in the package. The worker should not have to obtain or look at any other drawing, work package, standard, etc, to complete the task.

Outfit work station/zone information

The work station/zone information will be provided for shops, assemblies, modules, and zones. The product/stage chart is helpful in deciding the work packages. Work station information for shops for both processing and assembly will be required for hull fittings, pipe, sheet metal, foundation structure, joiner, paint, and electrical work. It is suggested that zone be used instead of the term work station for all onboard installation work package information. For *example*, work station installation information could be prepared for all on-block advanced outfitting work. Zone instruction information could also be prepared for the same type of product installation for all onboard advanced and remaining normal outfitting.

The work station/zone information prepared for the machinery spaces will be considerably simplified compared to the traditional engineering approach. This is mainly due to

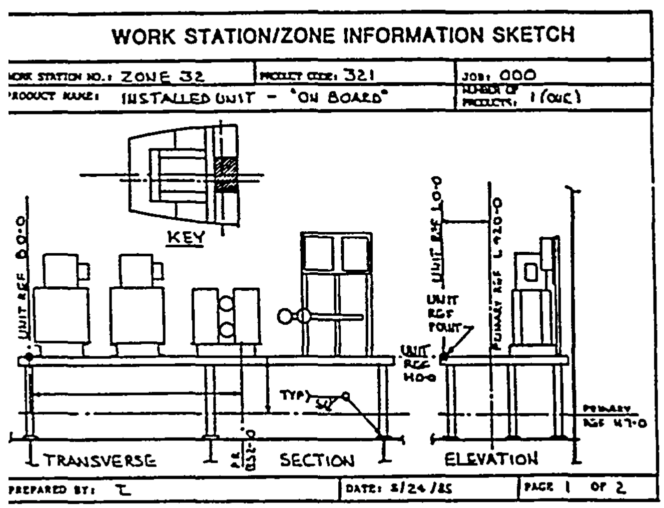
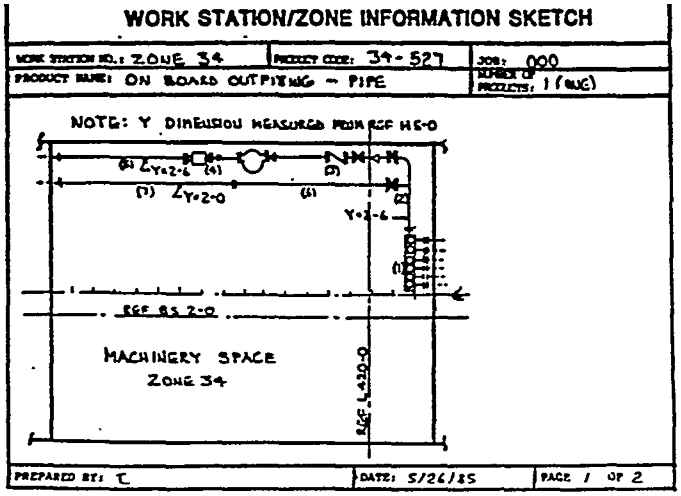


Fig. 24 "On board" advanced outfitting unit installation work station information



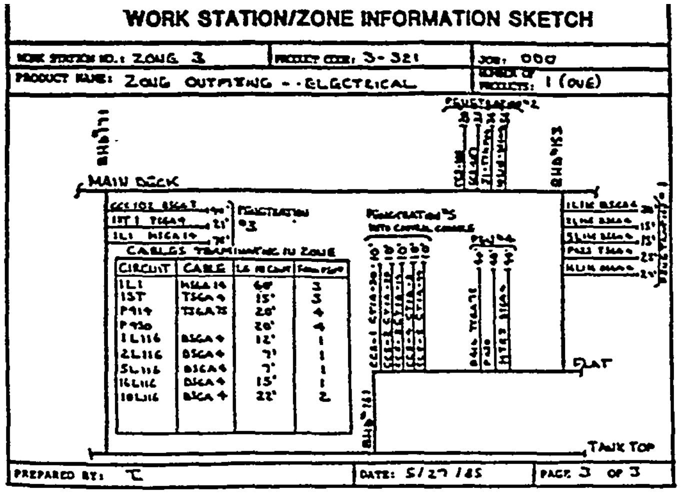


Fig. 25 pipe assembly installation work station information (parts list)

the logical breakdown of the total machinery space design and engineering, and the provision of work station/zone information packages in place of traditional working drawings. The machine arrangement becomes a series of major pieces of machinery, units, and connecting system corridor/floor plate Units. However, the quantity of information provided to production is vastly increased in scope compared to traditional engineering, plus-all systems are given equal depth of consideration and are shown to the same detail.

Work station information for shops for both processing and assembly will be required for foundation structure, pipe, sheet metal, paint, and electrical work. Work station information will also be required for machinery installation, etc, for units.

One area where electrical product engineering can save significant electrical production man-hours is in identifying cables on each wireway, identifying cables starting and ending in each compartment, providing required length of cable for each run, and length of cable in each space where it starts or ends.

Electrical fixtures in accommodation spaces should be located on the joiner work zone information sketches. All distribution panels, controllers, junction boxes, and other electrical equipment must be shown and located on installation sketches. The support connections to the structure should be included in the structural assembly and/or module work station sketches.

Figures 21 through 28 are typical work station/zone instruction sketches and lists for outfit.

Material requirements

Figure 29 summarizes the material definition approach for Engineering for Ship Production. It shows how the major equipment is defined by purchase technical specification during contract design. The majority of raw material is defined by advance material order per system during functional design. During transitional design, all material remaining to be defined is identified. Also, through the Product/stage chart approach, the preparation of the zone/unit lists is started. The sorting function, shown in Fig. 29 under work station/zone information, corresponds to the product/stage chart approach to work station parts list preparation.

A major requirement to ensure success of any material definition system is a detailed preparation and issue schedule compatible with the material ordering and *material receipt* requirements to construct the ship to plan. This integration of schedules must be a dynamic system, changing as

s followed even when it makes no sense.

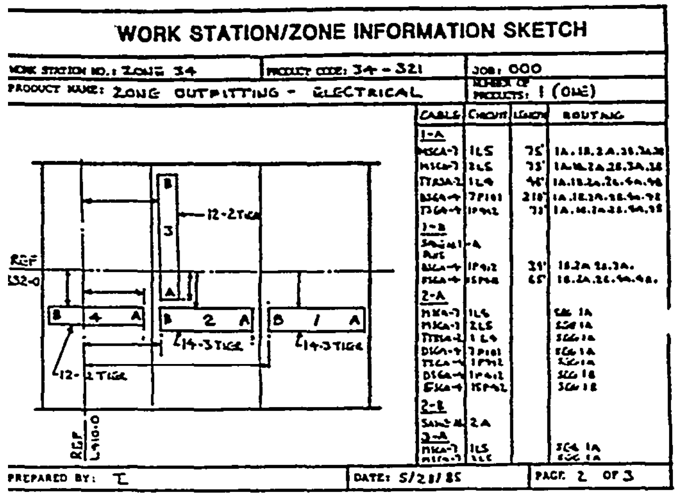


Fig. 27 Zone information, wireway and cable routing/lengths

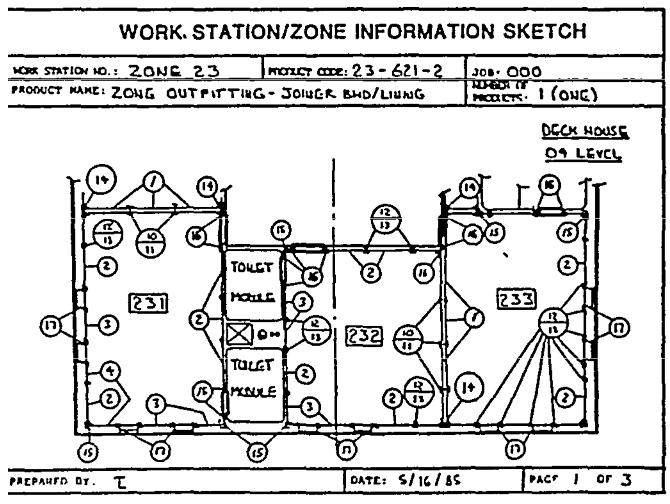


Fig. 28 Deckhouse zone information for joiner lining and bulkheads

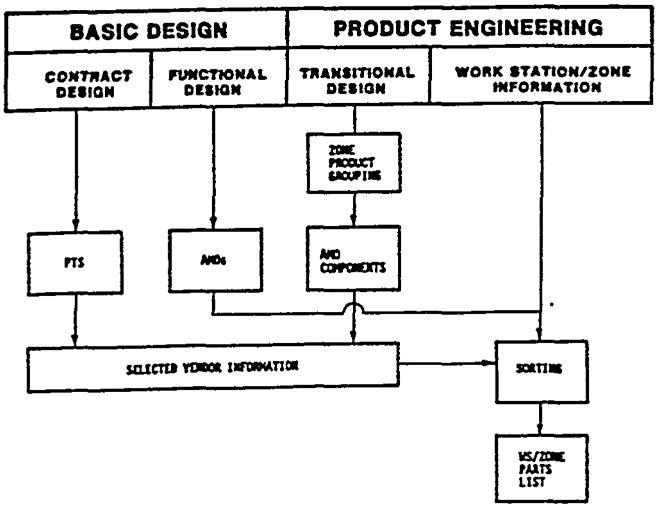


Fig. 29 Material definition phases

CAD/CAM and Engineering for Ship Production

The major difference between manual and CAD design and engineering is that all manual approaches are based on producing drawings at various stages in order to record and transmit design decisions. The correct CAD approach is baaed on constructing a computer prototype from which data can be extracted at any stage in whatever format desired.

With manual design, it does not matter if the drawings at the completion of one stage are usable in the next. Usually the parts of ***the previous stage*** drawings are redrawn as needed for the continual development of engineering. In CAD, this same approach could be and sadly is still used. However, using CAD correctly and building a common data base from concept, or at least contract design through work instruction information, requires that each stage be prepared so that it forms the logical foundation for the next stage. This approach leads to the concept of an expanding database as shown in Fig. 30. This requires each designer to develop his work as a full-sized prototype in accordance with design to that stage and in correct location to all other spaces, structure, outfit, etc. for the ship. A designer cannot develop the details in isolation and then have someone else check to see if it fits, ***a*** current practice in traditional manual engineering.

Another major difference is that with manual design and engineering, the use of functional drafting and systems drafting approaches makes economic good sense. Since the objective of CAD is to model the complete ship and since the duplication of details is so simple, functional drafting and/ or systems drafting concepts need not be used.

The final format of the work station/zone information is limited to drawings, sketches, and lists in manual engineering. In CAD engineering, the options are many.

Although the CAD/CAM systems specifically developed for shipbuilding are usable in a number of ways, they were probably developed with a specific sequence of tasks in mind. Therefore, it is important that shipyard techniques, planning, scheduling, and material control desires and the engineering approach be at least conceptually developed when deciding which CAD/CAM system to use. The use of computers for ship design and engineering is a natural catalyst for Engineering for Ship Production since they force the user to document his approach and to develop a logical sequence and formalization for the methods used. While CAD and CAD/ CAM could be used to duplicate the traditional manual method and produce data in exactly the same traditional format and content it would not achieve all the possible benefits On the other hand, if CAD/CAM is utilized to prepare the information for the proposed Engineering for Ship Reduction, it would enhance the approach. The approach for Engineering for Ship Reduction and typical time frame is given in Table 4. It uses the normal shipbuilding language, such as lofting, structure, machinery, outfit, etc. However, it is perhaps of more benefit to consider them all interim products of the final product (the ship) as also shown in Table 4. The Engineering for Ship Production logic fits well with current computer system capability, but must be communicated to system developers for future development. Otherwise, it is possible that new developments will not perform the desired tasks in the best way for a shipyard,

Computers force the users to logically think out what they want to do and how they should do it before they start. Program flow diagrams, structured programming, etc. lead the user through the operation steps. In addition, since computer processing unit (CPU) use time is usually expensive, programmers have developed a basic need to efficiently develop the required data and to eliminate unnecessary steps and duplication of information.

These goals are an exact match-up with the goals of Engineering for Ship Production. As already noted, the biggest hurdle to overcome is the tendency to use computers to provide the same information currently available. Instead computers could be used to develop data such as a full-size prototype of the design from which necessary information to procure, fabricate, construct, and test the ship can be extracted and presented in the most effective way.

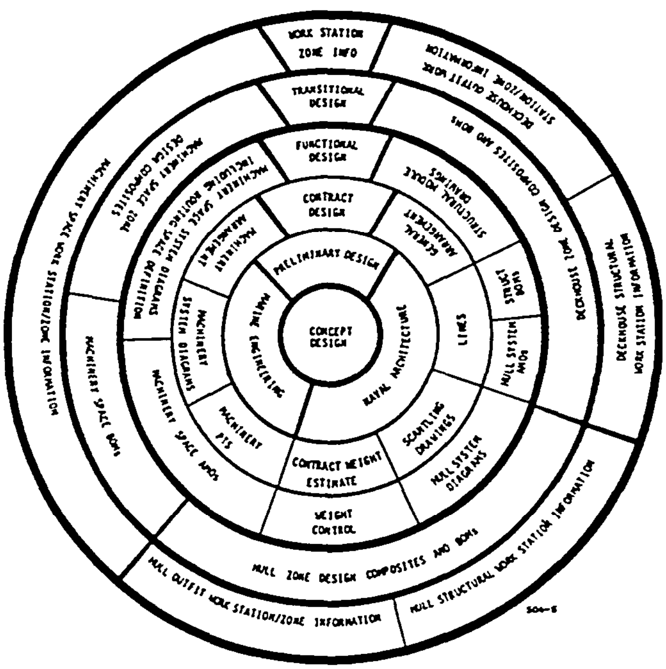


Fig. 30 Expanding ship design database

Technical support

In addition to functions and tasks described, engineering must provide the usual technical support for launching, in clining, tests and trials, ship configuration control, liaison etc. Engineering for Ship Production requires further addi tional tasks. The output from these tasks should be incor

Table 4 CAD/CAM data relationship

[A] NORMAL SHIPBUILDING TERMINOLOGY MAJOR DATA INPUT	TIME	DATA OUTPUT
(1) Construct Hull Definition	Month 1	
(2) Develop Structural Details (3) Develop Machinery Layout (4) Develop Distributive Systems	Month 2 to Month 8	
(5) Develop Electrical Details (6) Develop Joinerwork Details	Month 4 to Month 9	(1) NC Data for Structure Processing (2) Work Station Information for Assemblies (3) Work Station Information for Modules
	Month 6 to Month 12	(4) Work Station Information for Distributive System Processing (5) Work Station Information for Distributive System Assembly (6) Work Station Information for Distributive System Installation
	Month 12 to Month 18	(7) Work Station Information for Advanced Outfitting (8) Work Station Information for Electrical Installation (9) Work Station Information for Outfit Installation
	Month 9 to Month 24	(10) Work Station Information for Module Erection (11) Work Station Information for Module Welding
[B] FOR INTERIM PRODUCTS	TIME	DATA OUTPUT
(1) Develop Major Characteristics of Product	Month 1	
(2) Define Major Purchased Interim Products	Months 2 and 3	(1) PTS for Purchased Interim Products
(3) Divide Product into Zones	Months 2 to 4	
(4) Develop Detailed Model of Product Zone by Zone	Months 4 to 6	(2) CAM Information
(5) Identify Interim Products	Months 6 to 12	(3) Work Station Information for Interim Products

porated into the work station/zone information, where possible. These tasks include the following

1. Use group technology to classify and code products for production control to:
   - determine number of parts,
   - determine number of unique parts, and
   - select appropriate processing plan.
2. Determine joint weld length. This should be divided into weld type, size, and attitude.
3. Perform alternative design detail analysis.
4. Provide moving, turning and lifting analysis, and sketches for modules.
5. Provide access and staging sketches.
6. Provide blocking and temporary support sketches for assemblies, modules, and ship.
7. Include production, planning, scheduling, and material handling data/instructions in the work station/zone information as it is prepared by engineering.

There are many other items performed by the craftsman or supervisor in the traditional shipyard which need to be performed prior to work package issue in the modem shipyard. In many cases, these items can be effectively and efficiently performed by the engineering department.

Conclusion

If engineering is considered just another interim product in the shipbuilding cycle, a natural result is the analysis of the product process. This paper has proposed a particular process, which is considered in step with the current U.S. shipbuilding move to improve productivity and shorten build cycles through zone design and construction. Some shipyards are currently using similar engineering approaches and more will eventually follow. It is hoped that this paper will provide a forum for other engineers to discuss their approaches, ideas, and concerns about this critical matter.

Acknowledgments

The author would like to acknowledge with **thanks** the **support and encouragement** of colleagues and recent past and current **employers to present this** paper. However, the ideas described and the views expressed herein are solely those of the author and do not necessarily reflect those of any associate or company. Further thanks are given to professor Howard Bunch, chairman of the Education Panel (SP-9), for permission to present this paper, which is based on Part 2 of a ***report*** prepared by the author for the panel entitled "Engineering for Ship Production."

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J. D. F. Craggs and G. J. Bruce, A & P Appledore Limited

The author has produced a terse summary of a large and complex subject. In conjunction with his other recent publications [14] (additional references follow some discussions), this paper fills a significant gap in the literature on the design/production interface. The numerous references make this a valuable text for the student or researcher in this field of activity.

The author defines the **various** additional activities which an engineering department must perform in order to satisfy production requirements. These activities are currently ***per***formed by industrial engineering, by planning or, in the worst case, by supervisors during the production process. In order for these activities to be transferred to engineering, a number of conditions must be satisfied. These can be briefly summarized as follows [151:

l The ***need*** for a change in engineering must be clearly recognized by the design community, such that there is a commitment to provide timely information in the required format.

l The need to provide concise and relevant information from production to design/engineering must be recognized by the shipbuilder.

l A formal and structured communications system between design and production must be established.

l Ship design must follow a logical progression from concept to detail.

l Ship production must also follow a logical progression of interim products through specialized workstations.

l Both design and production must work within an overall, mutually agreed plan, and to strict schedules.

Within these conditions, the individual practitioners must be trained in the detailed application of design and production engineering techniques to do their work. The need for a systematic familiarization and training program cannot be over-emphasized. It is this role that reference 16 is intended to support. The author's work can therefore be seen as complementary to other work in the same field.

One point of some concern is the author's advocacy of a structural module drawing. Recent work carried out by the discussers' company has demonstrated that by reducing duplication and by consolidation, the number of drawings sent for classification society approval can be reduced by over 50 percent. Structural "system" information is provided by plans with sufficient detail (and references to standards) to allow material takeoff. The takeoff is on a basis which allows local material dimensional standards to be established and ensures early ordering. The module drawing is then replaced by the process analysis sketches, which define what information is to be produced at the detailed definition stage. This approach is effective in minimizing any extra effort required on the part of engineering.

For some years now we have been advocates of providing packages of information to the work station operatives as part of the overall revolution in the form and content of almost all technical information provided to design approval authorities and production. As a result of this, we consider that information provided to work stations should:

- match the work stage precisely;
- reflect in its information content the production methods to be used;
- indicate the accuracy standards to be achieved;
- show only that graphical information which is essential to the understanding of production: and
- view the assembly (for example) in the orientation in which the actual assembly will be seen by the work station operatives.

In the accomplishment of these objectives, the application of 3-D interactive computer aided graphic systems is most useful and versatile although there is still a great deal of scope for manually prepared isometric views.

The foregoing can be used to provide a basis for deriving the criteria by which the form and content of work station information packages can be judged. We believe it would have been more valuable if the author had replaced the numerous examples of workstation information with one or two, accompanied by the appropriate criteria. Reference [15] includes a proposed minimum set of criteria.

Additional references

14 Lamb, T., "Engineering Management for Zone Construction of Ships," JOURNAL OF SHIP PRODUCTION, Vol. 1, No. 4, Nov. 1985, pp. 266-

15 "NSRP Design for Production Manual: U.S. **Department of Transportation, Maritime Administration, 1985.**

R. H. Slaughter, Jr., Ingalls Shipbuilding

This paper provides an excellent definition of the problem of proper design for production, and does an outstanding job of suggesting a pattern or schema to resolve it. The statement in the second paragraph of the paper carries the crux of the problem of the industry. Truly, the changeover from a traditional craft organized shipyard to one of advanced technology should have had its second greatest impact on the engineering department. This condition arose for many reasons-perhaps the greatest ones being the nature and dollar value of the end product, the length of the contract period, the wide variety of disciplines involved, and the large number of parts needed to be designed, planned for, and built.

Another driver has been the traditional philosophy that the naval architect is the fountain of all knowledge, and thus he is not only expected to produce correct technical documentation, but also to resolve field errors in time to support production. That this paper addresses the problem in a concise manner is evident by comparison with a similar but far smaller process for the assembly of electronic equipment—meters, test equipment, stereo and television units, and computers by Heathkit and Schlumberger.

Heathkit concluded that their kitted components, to be assembled by untrained, inexpert, aficianados of the electronic component market, would have to be capable of construction by the general public using what we now know as "product oriented" design, material, and checkout documentation. In implementing this procedure, Heathkit put into effect the following policies:

1. The end product must work the first time. Thus, the design must be adequate so that reasonable tolerances would anticipate a working product.
2. Component quality should be of the highest grade to insure that they are no cause of end-product failure.
3. Instructions should be presented in "interim product" format. Sketches and corresponding instructions should be co-located in the instruction booklet, should be in isometric view, with all views mutually ***consistent.***
4. Instructions for "interim product" testing should be complete and clear.
5. Sketches and text should be clearly legible.
6. Bills of materials should be associated with the interim products, and there must be no short shipments.

The result of this technique of marketing was completely effective. Such a style fits the shipbuilding process, and is most consistent with the contents of this paper.

So, why are we talking about design for interim product production so many years after an electronic company so well demonstrated a successful modus operandi? Let's look at the differences and talk to the ones we can do something about. Again referring to the second paragraph of the paper, a major reason that engineering department did not "rise to the occasion" was that, because of the enormity of the task, they were unable to cope to the degree that they could maintain the necessary configuration discipline. This resulted in large cumbersome drawings showing all involved details —those that a worker needed to do a day's job, and many that he didn't. Today, where the base ship plans are in a data base, smaller segments can be printed out, or data can be used in the CAM mode, the immediately useful-information can be provided the worker, and it will be correct-disciplined to the master.

As to errors, and with specific reference to interference detection and resolution, CAD systems with 3-D interactive capability identify interferences so that the master in the database and the derived subdrawing are free of these errors. The volume of work needed is not a bar to the issue of production drawings and instructions for interim products.

The third major point to be made relates to the disciplinary control of the design, planning, and manufacture of ships. Engineering has a leadership responsibility to establish the controlling parameters of the configuration of the interim products as they are defined by basic manufacturing yard policy. Once the block breaks and schedule sequences are established, engineering is in the guidepoint position to tie the elements of the interim products (zones) together for all subsequent department.

This paper treats all of the foregoing concepts, and provides a procedure which, if followed, will assure the necessary and appropriate discipline to the design/manufacturing process of shipbuilding. At the risk of oversimplification, when the process is implemented, the building of ships and Heathkits will bear a most remarkable resemblance to each other—the differences being mainly in the order of magnitude.

F. Posthumus, Todd Shipbuilding

This excellent paper outlines today's problems in a forthright manner and provides practical advice for possible changes. It is not my intent to discuss the concepts or details of the subject paper, which are clear and concise. I like to emphasize the fact that, as we all know, the requirements of each contract are different and adaptation of the concepts outlined in the paper are to be considered.

The ideal situation where the shipbuilder is involved in the basic design phase, does not appear to be a feasible reality in the near future, since the decline in shipbuilding will enhance the continuous use of design offices; that is, very few shipbuilders are able to maintain an engineering staff of any significance. Furthermore, the lack of work or having a minimal workload in a shipyard also creates the "let us get started" syndrome thus eliminating the necessary engineering/planning lead time to prepare the production engineering data.

Some shipbuilders are willing to take a risk during the bid period to perform some of the functional design tasks as outlined in Mr. Lamb's paper; this could be a costly decision, but also provides advantages when the builder is awarded a contract.

Other areas outside the realm of the shipbuilder's control are customer requirements and the delivery of materials and equipment. As we all know, the customer, be it the Navy, U.S. Coast Guard, Army, or private company, still has the tendency to require a full set of detail design or working drawings for future use; that is, it is questionable if they will accept structural material lists, N/C tapes and shop-sketches in lieu of traditional system drawings. As a case in point, a customer recently requested us to remove any/all shop unique data, such as piece marks, material identification numbers, and zone numbers, from working drawings that were prepared for an overhaul job.

In regard to the planning effort as described in the paper, great flexibility in the preparation of work packages and scheduling will be needed due to the fact that the material and equipment procurement process requires considerable time and delivery dates are often unreliable.

In conclusion, it may still take some time before the various problems noted above are solved, but many items outlined in Mr. Lamb's paper can be accomplished and are being accomplished. The role of engineering is slowly being rec**ognized as part** of the overall shipbuilding strategy and the CAD system will certainly contribute to this.

I see the near future having fewer shipbuilders, but highly skilled ones that perform ***better as*** a team with a common goal of designing and building better ships at competitive prices.

Louis D. Chirillo, L. D. Chirillo Associates

This paper captures the shortcomings of traditional design practices. I can confirm the observation that the different logic successfully tranaferred from Japan to the U.S. shipbuilding industry, starting in 1979, did not spark most design organizations to assume "a lead position for directing and controlling change" [16].

One of the few exceptions is manifested by the impressive applications of product-oriented logic by the Puget Sound Naval Shipyard (PSNS) for modernization and overhaul work mostly in submarines. Designers were the initiators. but they would have made little progress without the contributions of a senior production manager who graped the logic and cooperated fully. What was essential for success, and what the author does not suggest, is meaningful production engineering input, a strategy, ***before contract design starts*** and constant refinement of the strategy as more definitive de sign information becomes available. Thus, each design phas develops in the context of production's strategy devised and refined before the fact. For example, in IHI's shipbuilding system, even diagrammatic which extend throughout the ship show tentative divisions by the specialities deck (other than accommodation and machinery), accommodation, machinery, electrical and, for a warship, weapons. Portions of the diagrammatic associated with each specialty and their material lists are subdivided into five to seven material ordering zones sequenced per production's strategy. This early material definition per production's strategy, while not yet exact, is of great assistance for effective material procurement and marshalling.

Another exception is the senior manager of a New York design firm who reviewed the NSRP publication "Integrated Hull Construction, outfitting and Painting"-May 1933, and stated "If only designers could get the attention of production people ***before contract design starts!"*** He already appreciated that it was archaic for a contract design to only describe what had to be built. Now, as disclosed by the NSRP publication "Pre-Contract Negotiation of Technical Matters"-December 1964, some U.S. shipbuilder are aware that they must control, or at least participate in, contract design.

The author does not adequately address the organization of people, information, and work. In PSNS, communications are greatly enhanced by ***product teams,*** ad hoc per product, each having representatives from production and design and from elsewhere commensurate with the complexity of the product assigned. Typical products so completed include an outfitted and painted grand block for a Tomahawk missile system and the transformation of submarine ballast tank

that need repair into overhauled tanks. Different types of work are controlled with sone/stage work instructions organized as 8½-by-11-in. booklets which do not reference any other documents. The booklets are effective because they benefit from production engineering before the fact.

Among U.S. private shipyards, two recognized that applying a product approach with archaic functional organizations meant that ultimately everything would be done on an ad hoc basis. Thus, in 1985 they both reorganized along product lines to some extent. The shift to product organization was made by major shipbuilding firms in Japan in the 1960s. The trend started in some U.S. industries other than shipbuilding, around 1950. In product organizations, people, information, and work, are organised the same way along product lines. Coat per product (interim product in shipbuilding) is of primary concern [17].

Where the NSRP publication "Product Work Breakdown Structure"—revised December 1982 describes the classification "zone/problem area/stage," the author proposes substituting "work station/zone information." Better control for material marshalling and production work is achieved when distinct stages are each the subject of a separate work instruction. For example, when a black is outfitted and painted upside down and afterwards right-side up, the schedule for implementation of zone/stage work packages controls so that no two teams are unintentionally scheduled to do different types of work in the same zone at the same time. All such stages may be implemented on the same work station.

For the successful organization of real and virtual work flows, three product aspects are essential:

- Zone-What is to be assembled?
- ***Problem area-Regardless*** of design details, what are the problems inherent in the required work so that the effort may be assigned to the correct work flow (production line)?
- Stage-When, relative to other work, should the required work be done?

Without "Problem Area," which the author proposes to omit, work flows per Group Technology concepts cannot be achieved.

The author has dwelled too lightly on a product work breakdown. What he has submitted in Table 1 is not a sufficient option in today's super competitive market. For example. engineering for ship production must appreciate that for typical merchant ships most hull blocks can be classified as flat-panel blocks. Through exploitation of transverse and longitudinal bulkheads and flat decks and shell, the production strategy for the Avondale-built Exxon product carriers resulted in over 70 percent of hull blocks being assembled on the flat-panel block production line. This included double-bottom blocks, as shown in the author's Table 1, which were assembled upside down. Because it was a major part of the hull construction effort, management applied priority attention to fine tune the flat-panel block work flow and the subordinate work flows which provided just-in-time support.

Also, the paper lacks sophistication in the complete absence of a description of how statistical accuracy control feedback is employed in engineering for ship production. Where is the mention of incorporating reference lines and reference points in structural drawings? What about design engineer's responses to the predictions of accuracy and productivity achieved through use of variation-merging equations? The most effective response is to modify design details and again analyze before production work starts!

Regarding the remainder of the author's paper, I see only an insufficient variation of the logic and principles employed in IHI's manufacturing system as disclosed by various NSRP end products.

Additional references

16 "Outfit Planning," National shipbuilding Research Program. Dec. 1979.

17 "Shipyard Organization and Management Development," National Shipbuilding Research Program, Oct. 1985

Author's Closure

The contributions made by the discussers towards the development of a better understanding of the relationship between engineering and production are greatly appreciated. I agree with most of the message presented by ***Messrs. Craggs and Bruce.*** My advocacy of a structural module drawing is based on the fact that U.S. shipbuilders have one customer at the moment and that customer, the U.S. Navy, requires structural drawings to be prepared. In this environment I suggest that they be modular rather than system oriented. I have no problem with the approach suggested by Messrs. Craggs and Bruce and in fact did exactly what they suggest for the Artubar tugs designed and constructed at Marinette Marine Corporation in 1977-79.

I appreciate ***Mr. Slaughter's*** comments and it is interesting that the database scenario he gives is the start of paperless engineering.

In reply to ***Mr. Posthumus, the*** proposed work station/zone instruction drawings would not be given to the customer. The functional design drawings, parts lists, etc. would meet the customer's contract deliverable requirements. If the proposed approach had been used, the case cited by Mr. Posthumus would not have occurred.

To have included all of the "omissions" cited by ***Mr. Chirillo*** would have required a sizeable report and not a paper with page restrictions. In the preparation of a technical paper the author must select what he considers important to the message he is trying to get across. However, the need for a production engineering input is stressed, as can be seen from Figs. 3 and 9 and the accompanying discussion, and Production Engineering considerations are most effectively integrated with the design group such that the need for a specialist separate group is avoided. Figure 3 shows that the Production Engineering function is performed along with the Contract Design for a specific ship design but what should have been made clearer in the paper is the major input of Production Engineering to what is called the "Shipyard Production Specification," which is shown in Fig. 9 as the "Shipbuilding Strategy."

The various considerations involved with the organization of people were not repeated here, as noted by Mr. Chirillo; this subject was given a detailed treatment in my paper "Engineering Management for Zone Construction of Ships." which was presented at the NSRP 1985 Ship Production Symposium, held at Long Beach, and to which Mr. Chirillo gave a meaningful discussion.

I certainly do not omit stage. Although I do not use the "zone/problem area/stage" notation as described by Mr. Chirillo, I, in fact, accomplish the same thing, as can be seen by my use of a Product/Stage Chart for each "problem area" as shown in Figs. ***10(a)*** and 10(b).

Mr. Chirillo correctly notes that the product definition, which is illustrated schematically by Table 1, entails sophisticated Group Technology principles that are not recounted here. Instead, those interested in this subject are referred to reference [3]. To touch upon the subject briefly, however, I would caution against using too much sophistication in many shipyards. Their shipbuilding strategy may not need it. Also, the yard people may not be able to understand it, thus causing more problems than it solves.

Mr. Chirillo correctly notes that the subject of accuracy

control is not covered in detail; however, the omission was intentional. That topic is discussed in my paper "Design for ***production in*** Basic Design," which was presented at the SNAME 1986 Spring Meeting. But for a more focused coverage of accuracy control, a companion paper to this one at the 1986 Ship Production Symposium, "The Establishment of Shipbuilding Construction Tolerances" by Butler and Warren, should be referenced; the discussion by Mr. Chirillo of that paper presents the approach taken by IHI in the application of this technology and is interesting in that respect.

Mr. Chirillo has had private discussions with me during the past six years covering the development of my approach to engineering for ship production. Because of this fact, I am puzzled by his observation that the approach presented ***is "an*** insufficient variation of the logic and principles employed in IHI's manufacturing system as disclosed by various NSRP end products." I used the approach almost in its current form starting in 1975 as reported in my 1978 paper "Engineering for Modern Shipyards." However, it has its origins back in 1954 and has been continuously developed since then. While the approach may appear similar to the IHI approach, there are significant differences and I suggest that the proposed approach can be helpful in presenting an alternative to the IHI approach when shipyards are developing their shipbuilding strategy.

EXERCISE 4

TEAM DEBATE ON DESIGN FOR PRODUCTION

NSRP SP-9 (EDUCATION AND TRAINING) PANEL
SHORT COURSE

DESIGN FOR PRODUCTION INTEGRATION

EXERCISE 4

WE WILL SPLIT INTO TWO GROUPS

TEAMS WILL BE ASSIGNED EITHER A FOR OR AGAINST POSITION

EACH TEAM WILL BE GIVEN 15 MINUTES TO DEVELOP TWO (2) STATEMENTS

STARTING WITH THE AGAINST TEAM THEY SHALL PRESENT FIRST STATEMENT IN 5 MINUTES OR LESS. OPPOSING TEAM WILL SELECT ONE PERSON TO RESPOND IN 5 MINUTES OR LESS. THEN THERE WILL BE 5 MINUTES OF GENERAL DISCUSSION

THEN THE FOR TEAM WILL PRESENT ITS FIRST STATEMENT AND THE SAME PROCEDURE FOLLOWED.

THEN THE SECOND STATEMENTS WILL BE PRESENTED THE SAME WAY

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Catalogue of Ship Producibility Improvement Concepts

Howard M. Bunch[1]

This catalogue is the product of a multi-year project to organize information relating to the improved producibility of Navy ships. This information is largely of a qualitative nature, and deals with all aspects of ship design and construction. Individual suggestions are presented in the form of very short abstracts. These are organized according to the Navy ship Work Breakdown Structure (WBS) coding system. The catalogue is intended to provide a ready reference of producibility information for the student and naval designer. This report has been prepared under the Memorandum of Understanding to Support Program Development in Naval Architecture and Marine Engineering between the United States Naval Sea Systems Command and the University of Michigan. It has been funded by an Office of Naval Research Grant (Number N00014-90-J-1404).

1. Introduction

THE PRINCIPAL objective of this project was to prepare a document of references that would relate a ship's system work breakdown structure (WBS) to concepts of construction producibility improvement. The database was constructed from a review of literature in several libraries at the University of Michigan end at the Naval Sea Systems Command Technical Library (in Washington, D.C.). From these references there was a culling to minimize repetition, yet which would give recognition to all relevant areas of the Navy ship systems. There was an annual review of literature to include new information that may have appeared, and which had not been previously called out.

There is an important constraint to the listing there was no attempt to authenticate the merits of any of the citations. It has been left to the reader to review the original source of the citation, and to make his (or her) own decision as to whether the suggestion is appropriate for his needs, and indeed, whether the suggestion is valid.

In addition to the author, there were numerous graduate students in naval architecture and marine engineering at University of Michigan who were involved in the literature search and cataloging effort. They were Harry Ocran, Brant Savander, Bryant Bernhard, John Immink, John Alguire, John Senger, David Amble, William Muras, Tom Ferrell, Jeffrey Kappel, Patrick Cahill, Sanjay Verma, and Alan Behning. Their effort was important, and is gratefully acknowledged.

2. Index Layout

The abstracts that were collected are organized according to the particular feature of the ship that they deal with. The U.S. Navy ship work breakdown structure (WBS) classification scheme is utilized. This system uses a three-digit numerical code to designate a particular ship area, structural component, or system. For this index the following major subject headings are used:

000 General (Comments
—Abstracts dealing with generalized producibility ideas, design considerations, and recommendations concerning the overall production philosophy of a Shipyard.

100 Hull Structure
—Abstracts dealing with design and construction of the shell, framing, bulkheads, decks and machinery foundations of the ship.

200 Propulsion Plant
—Abstracts dealing with the propulsion engine and associated auxiliary systems.

300 Electric Plant
—Abstracts deeding with shipboard electrical systems and wiring arrangement.

500 Auxiliary Systems
—Abstracts deeding with the climate control system, water piping, steering control and other auxiliary systems.

600 600 Outfit and Furnishings
—Abstracts dealing with the general idea of preoutfitting and outfitting in living, service and working spaces.

700 Armament
—Abstracts dealing with naval weapons systems and auxiliaries.

In the listing, shown in the next section, the above-mentioned major subject headings appear in boldface type, followed by underlined subheadings which classify the abstracts more specifically. Brief summaries of abstracts appear under the appropriate heading or subheading, preceded by a unique number. The abstracts are arranged in the body of the index using this number. The (Ref : appearing after the summary indicates the book or paper from which the abstract was obtained, along with the page number(s).

Example:

Information concerning transverse framing orrangements is desired. First look in the Producibility Check-Off List under the major subject heading 100 Hull Structure and read over the numerous subheadings. Reading down these subheadings, 117 Transverse Framing is found. After reading over the eight related summaries, the following seems most interesting:

[1]**NAVSEA Professor of Ship *Production* Science. Department of** Naval Architecture **end Marine Engineering, University of Michigan, Ann Arbor. Michigan.**

117.8 Increasing frame spacing will generally increase weight but will decrease weld length (Ref: N-19)

"N-19" indicates that reference N, page 19 is the source of this abstract. Reference N is listed under the REFERENCES section.

3. Producibility Check-Off List

000	**General Comments**
000.1	Design ship to facilitate assembly and erection with structural units, machinery units and piping units (Ref: K-257)
000.2	Establish unit breaks early in the design process (Ref: K-257)
000.3	Locate unit breaks for repetitive design and construction of the units (Ref: K-257)
000.4	Avoid excessively large units (Ref: K-258)
000.5	Block joints for engine-room double-bottom blocks are located above the grating level (Ref: M-55)
000.6	Where possible, each unit should have a flat area on which the remainder of the unit can be built up (Ref: L-71)
000.7	The maximum size of one unit and the maximum size of one flat panel should not exceed the capacity of each shop (Ref: L-71)
000.8	Where possible, P/S units should be similar (Ref: L-71)
000.9	The use of standard plate and stiffener sections should be maximized in a unit (Ref: L-71)
000.10	The maximum unit weight must not exceed the maximum lifting capacity or transporting vehicle which will handle it (Ref: L-71)
000.11	Weight of unit should be evenly distributed (Ref: L-71)
000.12	Allow parallel steel and outfit design to take place (Ref: R-1)
000.13	Provide work instruction information by "interim product" and zone rather than by "ship system" (Ref: R-3)
000.14	Producibility must be formally considered in "basic design" (Ref: R-5)
000.15	Concept of "notional" pipe banks and modules should be applied during allocation of space (Ref: R-7)
000.16	Design alternatives should be quantitatively analyzed for producibility (Ref: S-188-201)
068	<u>Integration and Engineering</u>
068.1	Hull construction, outfitting, and painting should be integrated (Ref: T-31)
068.2	Integrated Design Packages should be used in the overhaul of Navy ships (Ref: U-51-52)
070	<u>General Requirements for Design and Construction</u>
070.1	Preliminary design data should be available when performing detail design (Ref: V-120)
070.2	Standards should be applied to material identification and procurement (Ref: V-126)
070.3	Process capability of shipyard should be considered during design (Ref: W-139-140)
090	<u>Quality Assurance Requirements</u>
090.1	Accuracy of ship blocks should be measured to reduce rework during erection (Ref: X-244-246)
090.2	Shape and relative location of ship blocks can be determined using an optical measuring system (Ref: Y-114-119)
100	**Hull Structure**
100.1	When there is a tradeoff between steel weight and man-hours, conduct further analysis (Ref: K-259)
100.2	Design for use of automatic welding and other high-producibility tools (Ref: K-259)
100.3	Do not carry hull curvature into the structure inside of the hull plating surface (Ref: K-256)
101.1	Interval surfaces within the hull should be continuous wherever possible (Ref: B-3-2/202)
102	<u>CVK</u>
102.1	Height dependent on bilge radius and inner-bottom depth (Ref: B-3-2/202)
110	<u>Shell</u>
110.1	Strakes same direction as primary framing (Ref: I-120)
110.2	Plate thickness transitions should be less than 0.5 in. (possibly 1.5t—needs research) (Ref: B-3-2/528)
110.3	Area of stiffener is less than area of attached effective plating (Ref: B-3-2/528)
110.4	Lengths of standard shell plates are to be integer multiples of the web frame spacing (Ref: L-71)
110.5	Standard plate size should be a function of stiffener and web spacing, so they are common for each plate (Ref: I-130)
110.6	Bilge strakes have the same thickness as bottom plates (Ref: L-70)
110.7	Insert plates that are the full strake width may reduce work content (Ref: I-130)
111	<u>Shape</u>
111.1	Parallel midbody extended (Ref: B-3-2/106)
111.2	Sheer eliminated, or problems reduced by use of flat sheer w/knuckles (Ref: I-49)
111.3	Camber problems eliminated, or problems minimized by use of knuckles (Ref: I-49)
111.4.1	Bulbous bow: use simple shapes, and knuckle attachment to stem, worker access (Refs: I-68, A-IV.1.B)
111.4.2	Simplify bow and stem shape (Ref: I-55)
111.5.1	Stern: skeg w/knuckles (Ref: I-63.1)
111.5.2	Transom stern should be vertical and flat with sharp corner connection between shell and transom (Ref: I-55)
111.5.3	Stern frame should be easily fabricated as part of the stern module (Ref: I-68)
111.6	Section shape: flat bottom, sloped sides transitions with knuckles (Ref: I-63)
111.7.1	Curvature: flat panels, knuckles, single plane curvature; avoid double curvature (Ref: B-3-2/114)
111.7.2	Double curvature plates in single-screw afterbodies can be eliminated by locating the transfer from convex to concave plates at plate seams and erection butts (Ref: I-68)
111.7.3	Hull shape near and above design waterline should be flat or simple curvature (Ref: Z-126)
111.8.1	Locate knuckles at unit breaks. Do not place knuckles either at or between bulkheads or decks but 9 to 12 in. from the bulkhead or deck where the deck will be made (K-258)
111.8.2	Locate chines parallel to the baseline; they can be used as module breaks (I-68)
111.9.1	Width of flat keel should be at least enough to extend over the keelblocks to allow welding of the erection seam for P/S modules (Ref: I-63)

111.9.2	Flat keel width is shipyard maximum plate width (Ref: I-63)
111.9.3	If flat keel seam is used as an erection break, the flat keel width must suit the module-joining method, including the internal structure (Ref: I-63)
111.10	Straight and convex waterlines are preferable (Ref: I-55)
111.11	In achieving maximum section coefficient, sloped sides should be considered as an alternative to deadrise (Ref: I-63)
111.12	Deadrise involves considerable additional work content compared with a flat bottom (Ref: I-63)
111.13	Bilge radius should be determined so that the side module erection joint is above the double-bottom height or inboard of the tangent with the bottom in single-bottom ships (Ref: I-63)
116	Longitudinal Framing
116.1	Angles preferred over Tees (Ref: A-IV.5.D)
116.2	Continuity of spacing and of shapes (Ref: B-3-2/503)
116.3	Match block breaks to framing direction (Ref: I-120)
116.4	Framing in direction of straking (Ref: I-120)
116.5	Standardization of brackets and connecting arrangements (Ref: A-IV.5.A)
116.6	In a longitudinally framed ship, use bilge brackets rather than longitudinals in way of the bilge radius (Ref: I-148)
117	Transverse Framing
117.1	Best between cargo hatches (Ref: B-3-2/526)
117.2	Matched with strakes (Ref: I-120)
117.3	Advantage for longitudinally run distributed systems (Ref: I-45)
117.4	Reduce depth of beams to facilitate fitting pipe runs under beams rather than through (Ref: M-55)
117.5	Continuity, with the exception of the peaks (Ref: I-34)
117.6	Include permanent holes in web frames for staging pipe (Ref: I-148)
117.7	Transverse web frame spacings less than 5 m (Ref: L-70)
117.8	Increasing frame spacing will generally increase weight but will decrease weld length (Ref: N-19)
120	Bulkheads
120.1	Consider tank testing before erection (Ref: I-45)
120.2	Match structural functions, e.g., subdivision, fire protection, etc., and maintain continuity (Ref: B-3-2/502)
120.3	Provide portions of bulkheads on block to facilitate fitting pipe penetrations (Ref: M-55)
120.4	Fairing into ends; avoid "crank" into tanks (Ref: B-3-2/208)
120.5	Include permanent holes in N.W.T. bulkheads for staging pipe (Ref: I-148)
123	Trunks, Enclosures, Cofferdams
123.1	Arrange at block divisions (Ref: I-120)
123.2	Similarity in bottom and side (wing) structures (Ref: B-3-2/508)
123.3	Trunks provided in deckhouse for vertical system runs, even at expense of increased weight (Ref: M-55)
130	Decks
130.1	Common deck heights (Ref: C-24)
130.2	Continuity (Ref: B-3-2/202)
130.3	Camber eliminated or straight camber (Ref: L-70)
130.4	Floor spacing should be less than 2.5 m and be half the web frame spacing (Ref: L-70)
136	Double Bottom
136.1	Needs continuity, common spacing and height (Ref: B-3-2/503)
136.2	Innerbottom: keep flat, especially in machinery spaces for foundations (Ref: A-IV.8.C)
136.3	U versus V section (Ref: B-3-2/204)
136.4	Height accessible for workers (Refs: B-3-2/204, I-41)
136.5	Longitudinal floors vice two sets of longitudinal stiffeners in shallow double bottom (Ref: A-IV.8.D)
136.6	Overlap transition in change of innerbottom heights (Ref: B-3-2/204)
136.7	No need to keep traditionally sized lightening holes (Ref: I-41)
136.8	Transverse framing allows smaller double-bottom height (Ref: I-41)
150	Deckhouse
150.1	Flat and vertical surfaces (Ref: I-49)
150.2	Common modules for outfit (Ref: A-III.1)
150.3	Standard deck heights (Ref: C-24)
150.4	Transverse framing for reduced height (Ref: I-45)
150.5	Use of trunks, centerline passageway (Ref: G-11)
150.6	Provide only enough exterior decks to enable safe access and working of the ship (Ref: I-49)
150.7	Tween-deck height should allow for high productivity overhead installations (Ref: I-45)
161	Structural Castings, Forgings, and Equivalent Weldments
161.1	Standardize Navy vehicle tie-down design (Ref: Z-127-128)
180	Foundations
180.1	Use of epoxy chocks (Ref: E-1-2)
180.2	Multiple pieces on a foundation (Ref: I-161)
180.3	Minimize number of parts and unique parts (Ref: I-161)
180.4	Do not mix plate and shapes; i.e., foundation all plate or all shape (Ref: I-161)
180.5	Standardize on a few structural shapes (Ref: I-161)
180.6	Run support vertical (Ref: I-161)
180.7	Integrate "structural back-up" with foundation (Ref: I-161)
180.8	If securing bolts are not easily accessible, use studs (Ref: I-161)
180.9	Eliminate fitting joints, maximize lapping design (Ref: I-161)
180.10	Use sheet metal independent drip pans in lieu of built-in (Ref: I-161)
180.11	Incorporate foundations for deck machinery into equipment (Ref: I-179)
200	**Propulsion Plant**
200.1	Symmetry (Ref: I-35)
200.2	Standardized (Ref: A-III.4)
200.3	Modulize engine room (Ref: Q-151)
200.4	Systemically grouped (Ref: F-7)

200.5 Equipment removal routes (Ref: C-23)
200.6 Avoid unit breaks across machinery spaces, especially major foundations (Ref: I-199)
200.7 Block joints for engine room double-bottom blocks should be located above the grating level (Ref: M-55)
200.8 Arrange machinery to minimize piping runs and improve operation and maintenance (Ref: K-258)
200.9 Place machinery installations for shop assembly and testing (Ref: K-258)

250 Systems Grouping
250.1 Equipment-association list should be prepared during on-unit outfitting for major machinery (Ref: I-1.7.3)

260 Support Systems
260.1 Integration with structure (Ref: I-199)

262 Lube Oil
262.1 Associate with equipment (Ref: I-1.7.3)

264 Lube Oil Handling
264.1 Minimize piping run lengths (Ref: I-202)
264.2 Valves should come up to the side of the grating and floor plates (Ref: I-206)
264.3 Use FRP piping where applicable (Ref: O-1-24)
264.4 Use removable-stud type pipe couplings between modules (Ref: P-4-5)
264.5 Run pipes parallel to ship's x-y-z axis (Ref: M-55)

300 Electric Plant
300.1 Grouping and Routing (Ref: B-3-2/402)
300.2 Systems grouping near distribution centers (Ref: I-225)

320 Power Distribution
320.1 High voltage main distribution (Ref: C-9)
320.2 Cable breaks at unit breaks (Ref: I-225)
320.3 Post vice two-arm hangers. Avoid wire pulling situations (Ref: I-225)

500 Auxiliary Systems
500.1 Grouping and Routing (Ref: B-3-2/204)
500.2 Proximity to distribution system (Ref: C-9)
500.3 Dedicated distribution system (Ref: H-1,2,9)
500.4 Access and equipment removal (Ref: I-206)
500.5 For zone-oriented pipe runs, locate surfaces of pipes to be on same plane, not their centerline (Ref: M-58)
500.6 Minimize piping run lengths (Ref: I-202)
500.7 Valves should come up through and to the side of the grating and floor plates (Ref: I-206)
500.8 Use FRP piping where applicable (Ref: O-1-24)
500.9 Run pipes parallel to ship's x-y-z axis (Ref: M-55)
500.10 Use removable-stud type pipe couplings between modules (Ref: P-4-5)

510 Climate Control
510.1 HVAC runs in trunks (Ref: G-11)
510.2 Combine with other distributed systems (Refs: H-10, I-221)
510.3 Simplify shaped-duct sections (Ref: I-221)

520 Seawater
520.1 Pipe bends not greater than 2 pipe diameters (Ref: G-13)
520.2 Locate inboard to avoid following hull curves (Ref: H-2,9)

560 Ship Control Systems

561 Thrusters

562 Rudder
562.1 Cantilevered spade is the easiest (Ref: I-161)
562.2 Constant section throughout depth (Ref: I-161)
562.3 Vertical leading and trailing edges (Ref: I-161)
562.4 Horizontal bolting coupling instead of taper with nut (Ref: I-161)

581 Anchor Handling
581.1 Simplicity of system: straight, chain pipe; stowage on deck vice hawse (Ref: A-IV.2.A)

600 Outfit and Furnishings
600.1 Standardize (Ref: C-3)
600.2 Arrange concentrations away from unit breaks (Ref: C-3)
600.3 Arranged for pre-outfit (Ref: C-3)
600.4 Grouping and Routing (Ref: B-3-2/402)

630 Preservatives and Coverings

631 Painting
631.1 Special coating tanks totally within a block (Ref: I-1.3.2 h)

635 Hull Insulation
635.1 Apply hull insulation to joiner linings and ceiling, instead of inside surfaces of hull and deckhouse structure (Ref: I-179)

640 Living Spaces
640.1 Use of composite dividers (Ref: I-179)
640.2 Standardize modules (Ref: I-179)
640.3 Keep furniture off deck, supported by joiner bulkheads (Ref: I-179)
640.4 Use carpet over bare steel in cabins (Ref: I-179)
640.5 Use modular galley equipment (Ref: I-179)

650 Service Spaces
650.1 Grouping to supply systems (Ref: B-3-2/304)

660 Working Spaces
660.1 Reverse framing in electrical spaces for false floors (Refs: C-16)
660.2 Use troweled-in-place deck covering (Ref: I-179)

700 Armament

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NATIONAL SHIPBUILDING RESEARCH PROGRAM

DAILY LOG

DESIGN FOR PRODUCTION INTEGRATION

DAILY LOG

The purpose of this daily log is for you to pick out and record the most personally significant experience of the day and what you learned from it.

This will involve reflecting on:

- what experience during the day was most significant to you personally
- why this was personally significant
- what you learned from it
- any actions you propose to take as a result

Of course, you need not restrict your record to only one experience.

You can also use the daily log to record your thoughts, ideas, insights and feelings. This may include reflections on what worked and what did not work (and why) and ideas for possible improvements. It may include reflections on the relevance of the course experiences to activities and experiences outside of the course.

DAILY LOG

DAY 1

WHAT WAS THE MOST PERSONALLY SIGNIFICANT EXPERIENCE?

WHY WAS THIS PERSONALLY SIGNIFICANT?

WHAT DID YOU LEARN?

WHAT ACTIONS WILL YOU TAKE OR PROPOSE AS A RESULT?

ALS0 RECORD ANY OTHER THOUGHT, IDEAS, INSIGHT AND FEELING

DAILY LOG

DAY 2

WHAT WAS THE MOST PERSONALLY SIGNIFICANT EXPERIENCE?

WHY WAS THIS PERSONALLY SIGNIFICANT?

WHAT DID YOU LEARN?

WHAT ACTIONS WILL YOU TAKE OR PROPOSE AS A RESULT?

ALSO RECORD ANY OTHER THOUGHT, IDEAS, INSIGHT AND FEELING

WORKSHOP EVALUATION

COURSE EVALUATION

We would be very grateful for your feedback on the course. Please complete this evaluation form and return it at the end of the course. Two copies are provided so that you can keep a copy of your evaluation. Thank you!

THE MOST HELPFUL THINGS I LEARNED FROM THE COURSE ARE:

1.

2.

3.

WHAT I LIKED BEST ABOUT THE COURSE WAS:

WHAT I DISLIKED MOST ABOUT THE COURSE WAS:

RECOMMENDATIONS FOR FUTURE COURSES

ANY OTHER COMMENTS?

NAME (OPTIONAL)

COURSE EVALUATION

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ANY OTHER COMMENTS?

NAME (OPTIONAL)

NATIONAL SHIPBUILDING RESEARCH PROGRAM

DESIGN FOR PRODUCTION INTEGRATION PERSONAL ACTION PLAN

DESIGN FOR PRODUCTION INTEGRATION

PERSONAL ACTION PLAN

In the light of your thinking and activities during this course, what are now your principal related targets or goals? Write the top three in order of priority:

1.

2.

3.

What actions will be necessary for you to achieve these targets or goals?

Your actions	Other people's action
1.	
2.	
3.	

For each of your three targets or goals, write below something that would be visible evidence that you had achieved them:

1.

2.

3.

Enter the dates that you plan to complete each of your targets or goals:

1.
2.
3.

NAME: DATE: